National Environment Commission
& Department of Agriculture,
Royal Government of Bhutan

Adapting to Climate Change through IWRM

Contract No. CDTA 8623-BHU

NATIONAL IRRIGATION MASTER PLAN

March 2016

Egis Eau &
Royal Society for Protection of Nature &
Bhutan Water Partnership

Abbreviations

ADB	Asian Development Bank
AMC	Agriculture Machinery Centre
BDBL	Bhutan Development Bank Limited
BWSI	Bhutan Water Security Index
CIMF	Central Irrigation Maintenance Fund
CMIS	Community Managed Irrigation System
CDTA	Capacity Development Technical Assistance
DHMS	Department of Hydrological and Meteorological Services
DLIDP	Dry Land Irrigation Development Project
DMF	Design and monitoring framework
DOA	Department of Agriculture
DRDP	Decentralized Rural Development Project
EDP	Economic Development Policy
EIIP	Existing Irrigation Improvement Project
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
FMS	Farm Mechanization Strategy
FNS	Food and Nutrition Security
FYP	Five Year Plan
GDP	Gross Domestic Production
GNHCS	Gross National Happiness Commission Secretariat
ICWMP	Integrated Crop and Water Management Project
IFAD	International Fund for Agriculture Development
IWMS	Irrigation and Water Management Section
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
KPI	Key Performance Indicators
KRA	Key Result Area
MCA	Multi Criteria Analysis
M&E	Monitoring and Evaluation
MCM	Million Cubic Meters
MIS	Management Information System
Mt	Metric Ton
NECS	National Environment Commission Secretariat
NIMP	National Irrigation Master Plan
NHIDP	New Hill Irrigation Development Project
NIWRMP	National Integrated Water Resource Management Plan
O&M	Operation and Maintenance
PAD	Project Appraisal Document
PAM	Project Administration Manual
RBC	River Basin Committee
RBO	River Basin Organization
RDC	Regional Development Center
RGB	Royal Government of Bhutan
RNR	Renewal Natural Resources
SFDIRP	Small Farm Development and Irrigation Rehabilitation Project
SPS	Safeguard Policy Statement
TNA	Training Need Assessment
TOR	Terms of Reference
UNDP	United Nations Development Programme
UNFDC	United Nation Capital Development Fund

USD	United State Dollars
WB	World Bank
WSIDP	Wet Subtropical Irrigation Development Project
WUA	Water Users Association

Glossary

Chhusups	Water caretakers
Chhuzhing	Levelled bunded terrace, also known as wet land
Dzongkhag(s)	Administrative unit – District
DzongkhagTshogdu	District Development Committee
Gewog(s)	Administrative unit – Block
GewogTshogde	Block Development Committee
Kamzhing	Sloping unbunded terrace (dry land)
Khimsa	Homestead (residential land)
Nu	Ngultrum (Bhutanese currency)
Zhaptolemi	Voluntary labor

Definition: improvement of existing irrigation systems

Modernization	It refers to improvement of existing irrigation systems with a focus to expand its irrigated area utilizing existing water source. It thus requires re-engineering of existing infrastructure with appropriate technology.
Renovation	It refers to improvement of existing irrigation systems with a focus to increase its irrigation efficiency and thereby cropping intensity. It does not require re-engineering of existing infrastructure. The focus will be more on dry season irrigation with appropriate technological and institutional inputs.
Bottleneck repair	It focuses on providing support for bottleneck repair of existing irrigation systems on piece meal basis.

Units of measurement and conversion

Acre	Measure of land areas. One acre = 0.404686 ha One ha = 2.47105 acres

Executive summary

The National Irrigation Master Plan (NIMP) of Bhutan is one of the main outputs of the TA 8623 "Adapting to Climate Change Through Integrated Water Resources Management" funded by the Government of Bhutan with support from the Asian Development Bank (ADB) and Japan Funds for Poverty Reduction. Other key outputs are: National Integrated Water Management Plan (NIWRMP), River Basin Management Plan (RBMP) for Wangchu Basin, and Strengthened Water Resources Governance. The TA 8623 was implemented between September 2014 and April 2016.

The main objective of the NIMP is to present a 15-year action plan and roadmap for the development of climate adaptive irrigation systems and irrigated agriculture in the country to help attain broad agriculture sector goals of food and nutrition security and enhanced rural incomes.

Preparation of the NIMP followed a participatory process of consultations composed of four stages. The first stage focused on assessments of the baseline situation and enabling environment, which was followed by an examination of available resources, mainly land and water. The second stage focused on irrigation planning to be achieved by harmonizing available resources, crop choices, and irrigation technologies. This was followed by a stage of intervention design and preparation of a roadmap for the development of climate adaptive irrigation systems and irrigated agriculture in the country. Finally, an investment plan was prepared through consultations with stakeholders.

The NIMP contains two parts and 14 chapters. The first part, consisting of seven chapters, presents the assessment of the baseline situation, enabling environment and available resources (land and water). Chapters 8 to 10 present the road map for irrigation and institutional development. Chapter 11 presents possible irrigation technologies following international best practices. Chapters 12 to 14 present pipeline projects and subprojects for irrigation development, project costing, benefit assessment, investment plan, economic evaluation, M&E plan, and recommendations. The chapters are summarized in the paragraphs below.

Assessment of the agriculture sector in Bhutan

Agriculture in Bhutan is largely subsistence-oriented, with low input/low output farming systems. It is characterized by the general integration of crop production with livestock rearing providing some farm inputs such as manure for fertilization. The extent of this integration, however, varies with the altitude and agro-ecological zones. Cropping systems are primarily mono-cropping with average cropping intensity slightly above 100%.

Cultivated land in Bhutan is broadly categorized into two types: Kamzhing and Chhuzhing. Kamzhing is a sloping, unbunded terrace where rainfed crops like maize, potato, millet, buckwheat, and orchards are grown. Chhuzhing is a leveled, bunded terrace where summer paddy is grown as the main staple crop. Chhuzhing can be irrigated or rain-fed. Of the several crops grown, paddy (rice) is the most important and preferred staple crop in Bhutan. As a result, production of paddy is also synonymous with food security, and has become an important national goal.

The planned development of Bhutan's agriculture sector began in the 1960's with the start of the first five-year plan in 1961. At that time, development activities were managed by the Ministry of Agriculture and Forestry. Later, early into the 9th Five-Year Plan (FYP) (2002-2008), development tasks were devolved from the central level to the Dzongkhags and further down to the Gewogs. This devolution also reshaped the development outlook, and investment in the agriculture sector declined gradually. As a result, the production of major cereals and their contributions to GDP have also declined, although some high value crops have seen their production and contribution to GDP increase.

In 2008, Bhutan went through a food crisis, which created a sense of urgency for the government to revitalize its food security policy. Since then, the country has re-embarked on a food and nutritional security policy with increasing investment in the agriculture sector.

Despite an increase in investment, Bhutan faces several challenges for agriculture development. These include: (a) lack of irrigation facilities and weakening public sector irrigation development capacity, (b) fragmented and declining areas under crop cultivation, (c) labor shortages (d) low agricultural productivity (e) wildlife depredation of crops (f) cheap imports from India (g) poor agricultural support services and (h) climate change.

However, Bhutan also has several opportunities for developing irrigated agriculture. These include: (a) existence of high-level political commitment, (b) availability of land and water resources, (c) increasing cultivation of high value crops and agricultural mechanization, and (d) unlimited markets in neighbouring countries.

Irrigation in Bhutan

Until recently, irrigation development in Bhutan was the result of the farmers' own initiatives and investments in the construction and management of traditional irrigation systems through the use of local resources and knowledge. These systems are called here community managed irrigation systems (CMIS). Over 1200 CMIS exist in the country, of which about 1000 systems are currently functional and irrigate about 64,248 acres of land.

The Government's involvement in irrigation development started with the 2nd FYP in the late 1960s. Since then, a couple of large-scale irrigation systems were built through donor assistance, which presently are also being managed by the communities.

Most of the existing CMISs are run-of-the-river types. They draw water from the second or third order tributary rivers whose flows depend almost exclusively on monsoon rains. Their infrastructure is generally in a poor state. Leaking earthen canals, frequent damage by landslides, inappropriate structures, and increasing competition over the use of water in some locations are some of the common problems encountered. CMIS infrastructure is exposed to deterioration by even slight increases in river floods and landslides caused by climatic variability, mainly rainfall patterns. These systems are thus highly susceptible to climate change effects.

Public sector institutions for irrigation development

The Engineering Division of the Department of Agriculture is tasked with the planning and development of irrigation systems throughout the country. Currently, this division is involved in the design of new irrigation systems and major rehabilitations of existing ones. However, its present capacity is limited as the engineering division does not have a specified irrigation section with specialized irrigation professionals.

In each district (Dzongkhag), there is an engineering division responsible for designing and implementing various kinds of engineering projects, including irrigation works. However, the kinds of irrigation works that are undertaken directly by the district administrations are limited to maintenance and repair of irrigation canals.

Prevailing policies and regulatory system

There is no dearth of national policies and regulatory systems in Bhutan for managing natural resources and irrigated agriculture. All of these policies are designed to support the country's overall development objectives of Gross National Happiness (GNH) that refer to peace, happiness and quality of life in more holistic and psychological terms. Further, most development policies in Bhutan are pro-environment with a focus on the protection and conservation of natural resources Some of the relevant policies in relation to NIMP are: Bhutan water policy (2013), Food and Nutrition Security (FNS) policy (2014),National Land policy (2010), Irrigation policy (1992 and 2012), and Livestock sector development policy (2012)

The Bhutan Water Act (2011), Water Regulation (2014), and Bhutan Land Act (2007) are related regulatory frameworks.

Some of the key policy principles that guide the preparation of the 15-year irrigation development roadmap of the NIMP are to: (a) enhance food and nutritional security of the country within the framework of existing land uses policies, (b) diversify irrigation for irrigating Kamzhing, (c) provide assured irrigation for Chhuzhing, and (d) optimize water utilization within the framework of IWRM.

Gaps in policy principles and/or implementation mechanisms have been noted. For example, although the food security and land management policies have clear principles, weaknesses have been observed at the level of implementation. Other policy gaps noted are: lack of indicators for monitoring irrigation performance, lack of clarity in the formation of water users associations, and a mismatch between irrigation and other policies.

Assessment of land resources

Land resources are assessed using existing land use and cadastral maps. Analysis suggests that the reported cultivated land and cultivable land represent 277,000 acres and 403,000 acres respectively, while the 2013 cropped area was only 208,000 acres.

The irrigation potential of a particular land area is determined by many factors, of which economics is one. In the present context, as several combinations of irrigation technologies with crop choices are possible, the irrigation potential of cultivable land is very much site specific. It is assumed that about 50% of the cultivable land in Bhutan is irrigable. This amounts to about 200,000 acres, while the currently irrigated area is only about 64,000 acres. The availability of land is not a constraint for irrigation development in Bhutan.

Assessment of water availability and demands

Assessment of water availability through surface runoff is examined at two levels: (a) at the level of existing irrigation systems for further development, and (b) at the level of each district. This assessment suggests that about 71% of the existing irrigation systems have either abundant or adequate water supply, while 29% of them have scarce or inadequate water supply. Thus, 71% of the existing systems can be improved to increase irrigated areas and/or cropping intensities, while the remaining systems (29%) can be upgraded only through water source diversification.

The assessment of water availability at the level of a district is performed using a couple of hydrological models, of which WEAP (water evaluation and planning) is one. Likewise, irrigation demand is assessed with the FAO developed CropWat-8 program using observed metrological data of class A weather stations. These assessments suggest that the availability of 80% dependable water at the level of a district will not be a constraint for developing new irrigation systems.

Climate change and impact on agricultural production

As noted above, CMISs are highly susceptible to changes in seasonal water availability, floods, and landslides, which in turns are influenced by anticipated changes in climatic parameters like rainfall and temperature. As a result, it is expected that climate change may not only negatively impact rain-fed agriculture, but also irrigated agriculture production.

Further, about three forth of the agricultural land in Bhutan is rain-fed and depend almost entirely on monsoon rains for crop production. Hence, the impact of climate change on Bhutan's overall agricultural production may be severe.

Analysis of available data suggests that agricultural production in Bhutan has not been increasing over the past few years. There is a risk that the situation will further deteriorate as a result of climate change. Although it is difficult to quantify the impact of climate change, it is predicted that agricultural production may decline by 4 to 10% in the future if appropriate measures are not taken to mitigate climate change.

Irrigation planning

For the purpose of irrigation planning, Bhutan is first divided into **five irrigation** zones. **Crops are then planned for each zone following** the national food and nutritional security policy that calls for a more diversified crop production system. Features of the irrigation zones, prevailing trends of crop productions and their contribution to GDP, and ongoing crop development programs have also been taken into consideration for crop planning under the NIMP.

The main crops planned to be irrigated under the NIMP include paddy, spring maize, winter potato, wheat, vegetables, orchards and other cash crops such as pulses, mustard, legumes, cardamom, ginger, chilli, etc.

In the same way as the planning and sequencing of crops to be grown, the targeted areas for irrigation development under the NIMP are estimated based on the food production requirements in line with Bhutan's food and nutritional security policy. Physical targets of the NIMP are for a planning horizon of 15 years (2032). They are presented below.

SN	Physical targets of NIMP		Unit	Baseline (2014)	Target (2032)
1	Achieve food self-sufficiency	Paddy	%	51	75
		Cereals	%	64	80
2	Irrigated areas (acres)		Acres	64,000	91,000
3	Crop production	Paddy	Mt	75,000	145,000
		Total cereals	Mt	170,000	192,000

Irrigation development roadmap

In order to achieve the food security targets, an irrigation development road map was designed with the four main components as listed below.

Infrastructure development	This component focuses on building infrastructure for irrigation development. Mainly two types of infrastructural projects are planned: (a) existing irrigation improvement project (EIIP), and (b) new irrigation development project (NIDP) Under EIIP, the CMIS irrigating about 64,000 acres will be considered through three different modes of interventions aiming to bring an additional 8,000 acres of new land under irrigation. Likewise, depending on the location and types of irrigation technology used, three categories of new irrigation development projects are proposed that aim to bring an additional 19,000 acres of new land under irrigation. This development will be supported by appropriate irrigation technologies following international best practices. In order to develop climate resilient irrigation systems, the climate change component will be mainstreamed in the irrigation planning process. This will be done by including a climate change vulnerability assessment at the level of the pre-feasibility and feasibility studies of the irrigation systems concerned. Proposed sub-projects will be prioritized accordingly based on their resilience to climate change. Irrigation systems developed under the NIMP will be handed over to the respective water user associations (WUAs) for operation and maintenance (O&M). However, the Engineering Division of the Department of Agriculture (DOA) will also be responsible for providing O&M assistance to technically demanding facilities. WUAs will be authorized to collect irrigation fees (IFs) from their users. Besides this, a self-sustaining Central Irrigation

	Maintenance Fund will also be established that will lend collateral, free soft loans to WUAs at a low interest rate for maintenance needs.
Land development and agricultural mechanization project (LDAMP)	The land development and agricultural mechanization component will be implemented in conjunction with other infrastructure projects. It contains three main sub-components: 1) land development, 2) agricultural mechanization, and 3) on-farm trail development.
Integrated crop and water management project (ICWMP)	This component integrates irrigation management into the crop production system. It aims to optimize the agricultural productivity of an irrigation system, and at the same time ensure sustainability of the developed irrigation infrastructure. The ICWMP will be implemented through two different approaches: (a) sector-wide approach and (b) project-specific approach.
Institutional development	Institutional development is a key component of the NIMP. It encompasses (a) DOA and its engineering units, (b) local governmental development organizations at the district level, (c) irrigation WUAs, and (d) private sector irrigation service providers.

In addition to the above, two components are considered under the NIMP: project studies & preparation, and implementation support services.

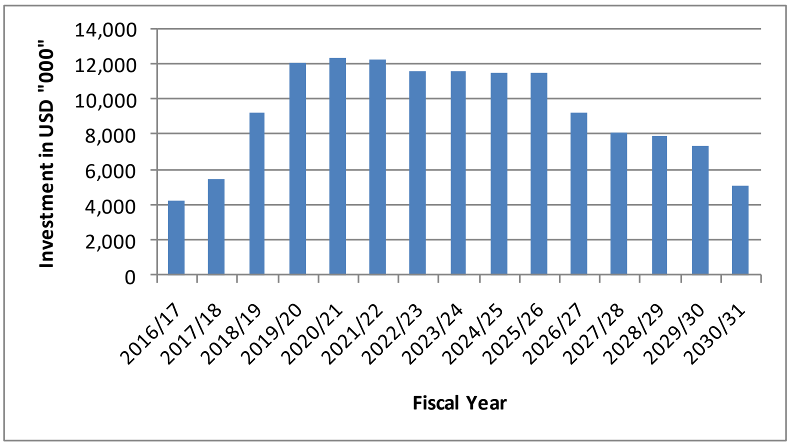
Long list of infrastructure development subprojects and project costing

The long list of subprojects for infrastructure development is elaborated from several sources: TA 8623 questionnaire survey, carry-over list of the 11th FYP, FAO Study 2010, and TA 8623desk study. The costing of subprojects is derived from past project experiences. The table below provides the estimated costs of the six NIMP components.

SN	Projects	Areas (acres)	Cost (million US$)
1	Project studies & preparation		6.4
2	Infrastructure development (including O&M)	91,000	64.85
3	Land development and agricultural mechanization	15,000	38.2
4	Integrated crop & water management	33,200	17.4
5	Institutional strengthening & capacity building (DOA, WUA, District units, private service provider)		5.75
6	Implementation support services		7.4
		Total	140

Investment plan

The total NIMP investment will be of about US$140 million for the next 15 years. It is expected that the actual implementation of the NIMP will start from the fiscal year 2016/7.This means that the last two years of the 11th FYP will overlap with the NIMP. As the investment ceiling of the 11th FYP has already been fixed, the NIMP planned investments for the first two years are kept in line with the already allocated budget of the 11th FYP. The figure below shows the expected annual funds allocation of the NIMP's investment plan.



Benefits on investment and economic analysis

There are two main types of benefits (returns) on investments: direct and indirect. Direct benefits from irrigation relate to an increase in crop production. It is expected that with the implementation of the NIMP, overall irrigated cropping intensity will increase from 103% to about 159% with increases in agricultural production from 114,425 to 316,724 Mt.

The main indirect benefits of NIMP include: (a) enhancing food security, (b) creating rural employment opportunities, and (c) contributing to further development of the livestock subsector and micro agro-industries.

An economic analysis compared two options, one with the proposed investment and one without the NIMP or the "baseline scenario", and presented the economic indicators in terms of numbers as well as in a non-deterministic fashion, or probabilistically. Statically, the benefit cost (B/C) ratio is above 2 across the entire discount range while the net present value (NPV) remained around US$100 million. Even under the worst scenario, the NPV still amounts to US$40 million, which still yields a B/C ratio of about 1.5 overall. These indicators thus suggest that the NIMP is worth implementing

Recommendations

Recognizing that irrigated agriculture cannot be developed efficiently without appropriate agricultural and institutional support services, the following recommendations need to be considered in the NIMP:

- Land pooling for mechanized farming
- Proper agriculture support services and agricultural subsidies should be in place
- Public, private, and community participation in the agriculture sector need to be further supported
- Engineering division (DOA) needs strengthening
- As thegovernment aims to limit the size of its civil service, the engagement of the private sector or private entities need to be promoted for irrigated agriculture support services
- Possibility of cooperative commercial farming needs to be explored
- Irrigation policy needs revisiting mainly in areas related to (a) irrigation of Kamzhing, (b) private sector investment in irrigation, (c) distinction between small and large irrigation systems, and (d) indicators for irrigation performance
- Water regulation should address: right of way for canals, categorization of irrigation systems for development planning, and non-resident water users.

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1. Introduction

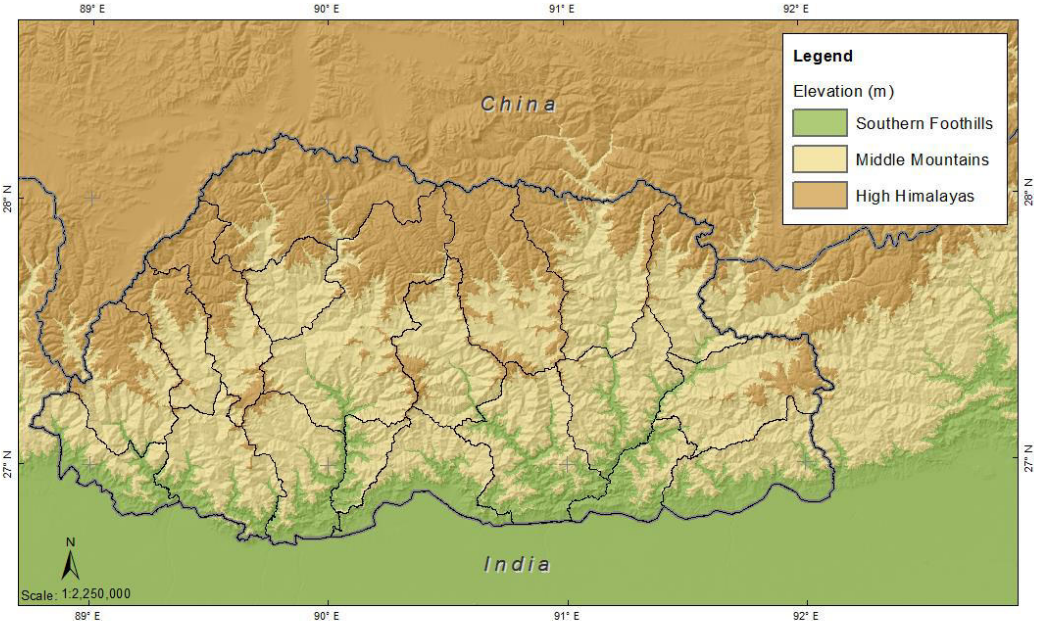
1.1 Country overview

The kingdom of Bhutan is a landlocked country located in the Eastern Himalayas and sandwiched between two giant countries: India on its south, east and west, and China on the north. The country has roughly a rectangular shape. Its length along east-west direction is around 300 kilometres (longest), while its maximum width in the north-south direction is about 170 kilometres. The total area of the country is about 38,394 square kilometres. Administratively and politically, the country is divided into twenty districts locally known as Dzongkhags and 205 Gewog (sub-districts).

1.1.1 Physiography

Bhutan is predominantly a mountainous country. Its elevation varies between 97 m in the south-east corner of the Zhemgang District[1] and over 7500 meters high great Himalayas in the north. Traditionally, the country is divided into three physiographic regions: high Himalayas, middle mountains and valleys, and southern foot hills. Figure 1.1 presents the physiographic map of Bhutan

Figure 1.1: Physiographic map of Bhutan



Source: ADB TA 8623

The northern part of the country consists of high Himalayas with an arc of glaciated mountain peaks with an arctic climate at the highest elevations. Alpine valleys in this region provide pasturage for livestock tended by a sparse population practicing transhumance.

The middle mountains that range between 1,500 meters and 2,700 meters above sea level are southward spurs of the Great Himalayan Range (NSB, 2013). The Black Mountains, in central Bhutan, form a watershed between two major river systems, the Mo Chhu and the Drangme Chhu. These rivers

1 At point where the Manas River enters into Assam, India; Refer: http://en.wikipedia.org/wiki/Geography_of_Bhutan

along with their tributaries have carved out spectacular gorges, terraced hill slopes, and fertile river valleys in the lower mountain areas. Most of the settlements in the middle mountains are located in and around these terraced hill slopes, and river valleys.

The southward foothills of the middle mountains, also known as Southern foot hills, or Siwalik Hills constitute the third physiographic region of the country. This physiographic region extends from east to west and the areas are covered with dense forest, alluvial lowland river valleys, and hills that reach to around 1,200 meters above sea level. The foothills descend into the subtropical plain located in India.

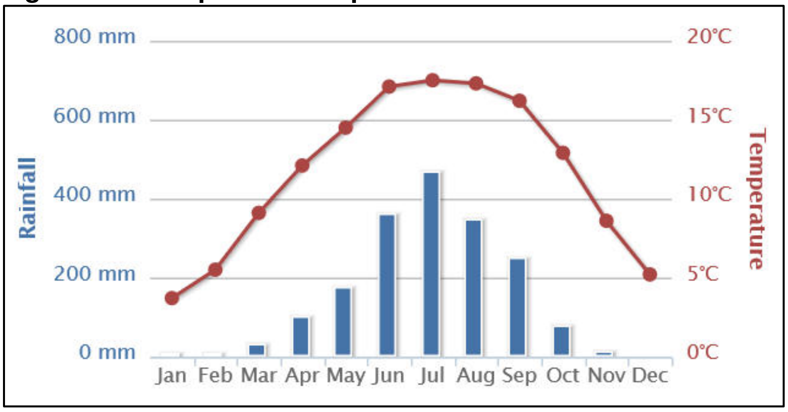
1.1.2 Population

The estimated population of the country as of 2014 is 745,153 persons out of which 387,520 persons (52%) are male and 357,633 (48%) are females. Bhutan's present population growth rate is about 1.3%. It is expected that the country's population by 2032 will be close to 900,000 inhabitants. Over 60% of this population is engaged in agriculture. As per the 2005 census, the then Bhutan's urban population was around 31%.

1.1.3 Climate

Bhutan is typically divided into three climatic zones: subtropical in the southern foothills, temperate in middle mountains and valleys, and alpine in the northern part of the country. The subtropical climate of the southern areas is commonly hot and humid during the monsoon and chilly during winter, with an annual precipitation ranging from 2500mm to more than 5000mm. The temperate zone of the middle mountains and valleys is cold in the winter, balmy in spring, hot in summer and mild in fall, with annual precipitation ranging between 1000mm and 2500mm. Finally, the alpine climate of the northern area is cold throughout the year. Annual precipitations in this area are limited to 500mm to 1000mm.Figure 1.2 and 1.3 present temperature and rainfall maps of Bhutan, while Figure 1.4 presents the map on reference crop evapotranspiration (ET_0)

Figure 1.2: Temperature map of Bhutan



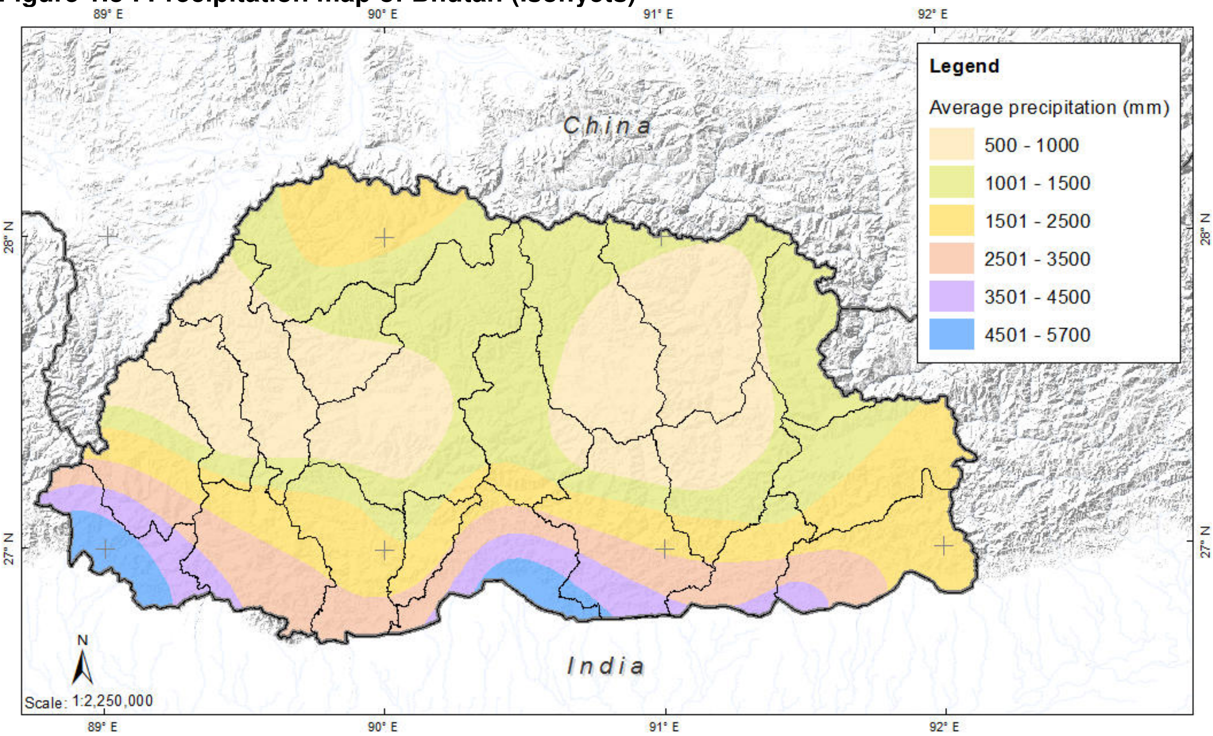
Source: World Bank/Climatic Research Unit (CRU) University of East Anglia, 2015[2]

1.1.4 Water resources

Bhutan is endowed with enormous water resources draining 2,238 m3/s or 70576 MCM annually (TA 8623 R1, 2016). This means that about 94,500 m3 of water (average) is available to each Bhutanese on an annual basis, which seems to be the highest in the region. All these water resources drain to Brahmaputra River in India through four main rivers and a couple of small southern waterways. Figure 1.5 presents the river basin map of Bhutan, and Table 1.1 provides some details on the main rivers.

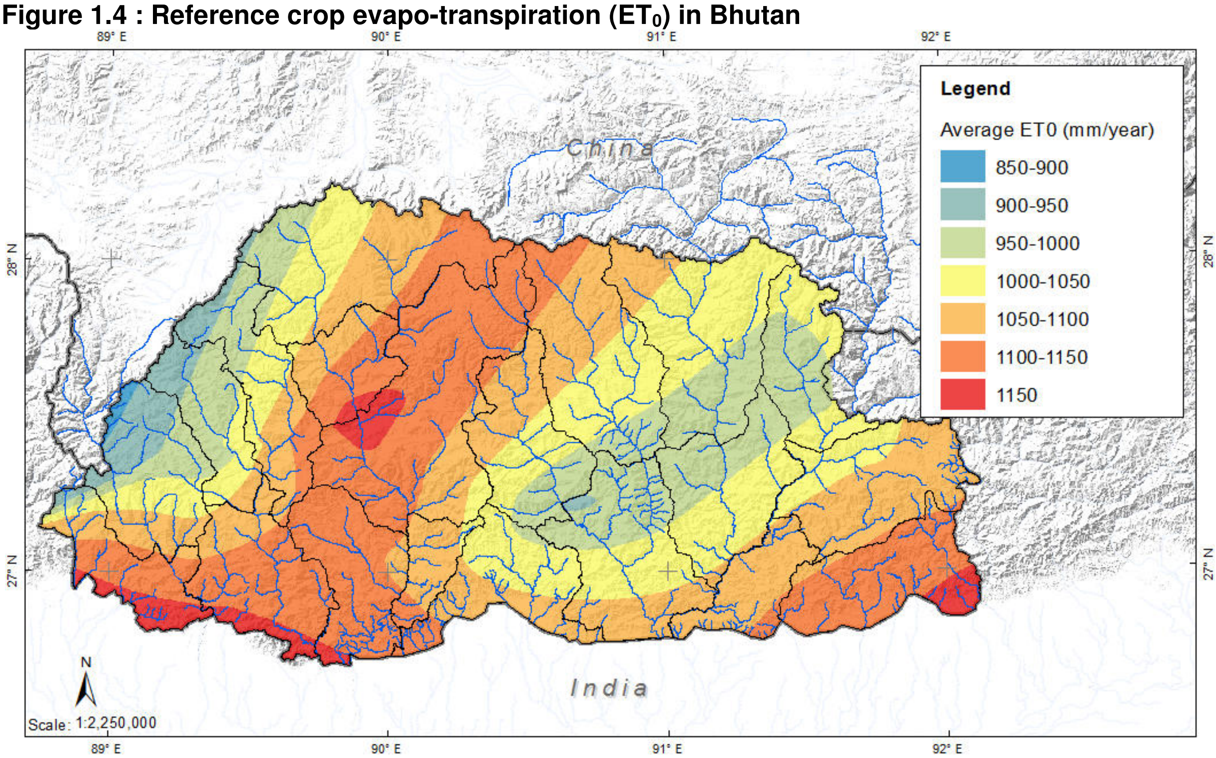
2 Cited by Charles Rodgers (2015)

Figure 1.3 : Precipitation map of Bhutan (Isohyets)



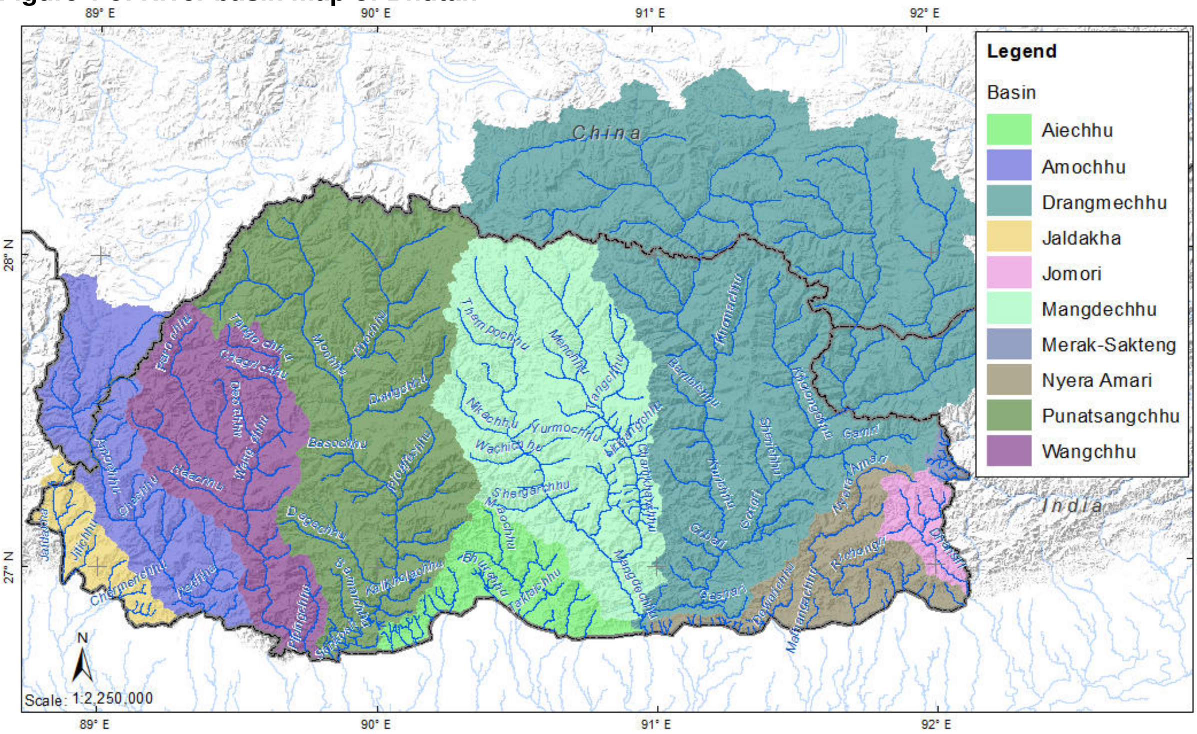
Source: ADB TA 8623

Figure 1.4 : Reference crop evapo-transpiration (ET_0) in Bhutan



Source: ADB TA 8623

Figure 1.5: River basin map of Bhutan



Source: ADB TA 8623

Table 1.1 : Rivers draining from Bhutan

SN	Basin / sub basins	Basin / sub basin areas (sq.km.)				Features
A	Main basins	Bhutan	China	India	Total	
1	Drangme Chhu	8,457	12,507		20,964	Over 60 % watershed in China
2	Mangde Chhu	7,380			7,380	Covers 19 % of the country
3	Punatsang Chhu	9,645			9,645	Flows through Punakha
4	Wang Chhu	4,596			4,596	Flows through Thimphu
5	Amo Chhu	2,310	1,605		3,915	Smallest main basin
	Sub totals	32,388				Covers 83 % of the country
B	Sub basins					
1	Merak-Sakteng	137			137	In Samdrup Jongkha area
2	Jomori	642			642	In Samdrup Jongkha area
3	Nyera Amari	2,348			2,348	In Samdrup Jongkha area
4	Aie Chhu	1,937			1,937	Mostly in Sarpang District
5	Jaldakha	942		87	1,029	Mostly in Samtse District
	Total	38,394	14,112	87	52,593	

Source: ADB TA 8623: basin areas computed using land uses maps (MOAF, 2010)

The five main rivers, draining 83% of the country's areas (Table 1.1), carry large volumes of flow and sediment during the monsoon season. Further, these rivers generally have steep gradients and narrow steep-sided valleys. As a result, they are hardly used for irrigation. The surface water sources that are being used for irrigation are the second or third order tributaries of these main rivers.

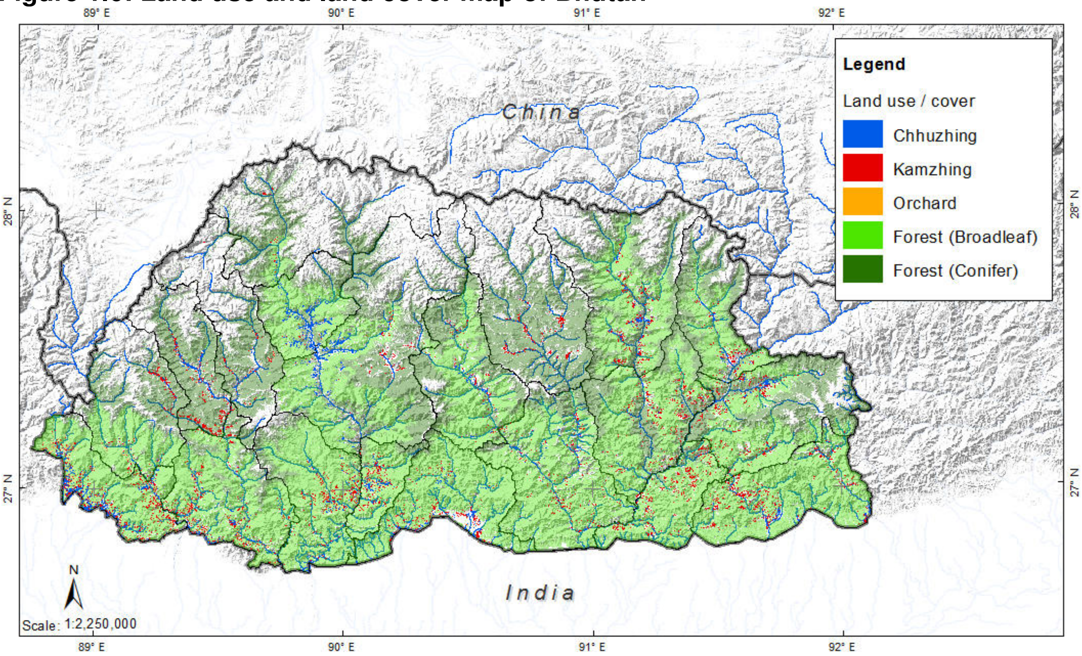
This means that despite the fact that Bhutan has abundant water resources (70,576 MCM per year) water is not necessarily available for irrigation. What is available for irrigation is the water that flows through the small rivers and streams in the headwater of the watersheds.

These small streams and waterways are mostly un-gauged. As a result, assessments of water availability from these rivers are difficult.

1.1.5 Land resources and land uses

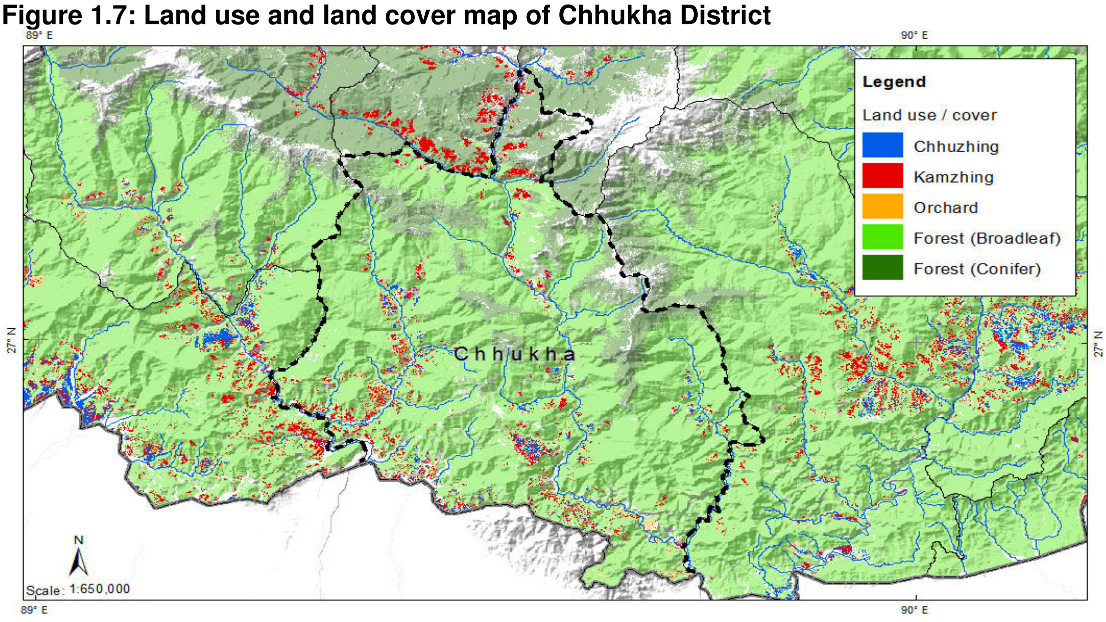
The total land area of the country is about 38,394 square kilometres. About 70.5% of this area is covered with forests, while the shrubs and meadows constitute about 14.5%. Similarly, the water bodies (including snow covers) and the agricultural cultivated land account for 8.2% and 2.9% respectively of the country's total area. Figure 1.6 and 1.7 present the land use and land cover maps of Bhutan and Chhukha District respectively, and Figure 1.8 presents the corresponding surface areas in square kilometres.

Figure 1.6: Land use and land cover map of Bhutan



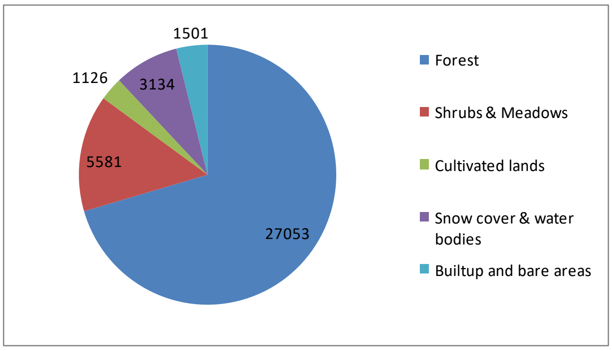
Source: ADB TA 8623

Figure 1.7: Land use and land cover map of Chhukha District



Source: ADB TA 8623

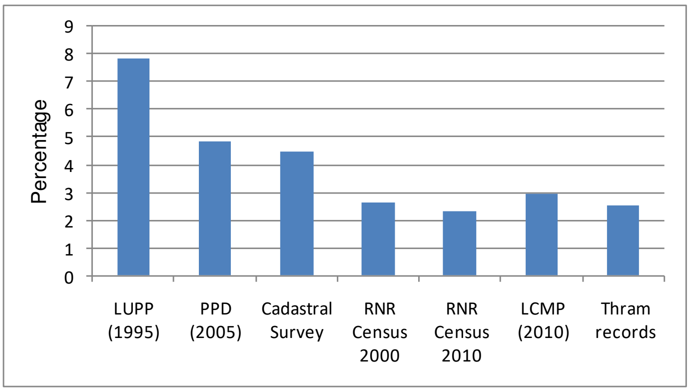
Figure 1.8 : Land use and land cover in Bhutan in square kilometres



Source: (MOAF, 2010)

Of the above types of land use and land cover, the area under cultivated land is the concern of this master plan. Though MOAF (2010) estimates its coverage to be 2.9% of the country's areas, other studies and land mapping projects present different figures. This is reflected in Figure 1.9 below.

Figure 1.9: Percentage cultivated land area according to different sources



Source: (MOAF, 2010)

Note: LUPP: Land Use Planning Project; PPD: Policy and planning division, Ministry of Agriculture and Forest; RNR: Renewal Natural Resources; LCMP: Land Coverage Mapping Project; Thram record: A written inventory (with number) of landholdings (in acre) in the country originally derived for the purpose of taxation;

Figure 1.9 suggests the existence of considerable uncertainty with regard to the area of cultivated land in Bhutan, though the assessment through cadastral maps seems to be the most accurate. The LUPP (Land Use Planning Project, supported by DANIDA) estimated its coverage to be 7.9% in 1995, while the LCMP in 2010 estimated it to be 2.9%. Some of the main reasons for this deviation as reported by MOAF (2010) are: (a) change in demarcation of international boundary of the country[3], (b) advancement in methods used for land assessment, (c) decreasing areas under cultivated land due to increasing urbanization, and so on.

1.1.6 Farming systems and main crops

Farming systems in Bhutan are generally for subsistence. They are characterized by the general integration of crop production with livestock raising and the use of local forest products for some farm inputs. The extent of this integration, however, varies with altitude. For example, in the higher altitude (northern mountains), animal raising dominates the production of cereal crops, while in the middle mountains and southern foothills, crop production dominates the animal farming. Table 1.2 provides general outlook for farming system in Bhutan.

3 The recent change in demarcation of international boundary in the northern part of the country has changed the total area of the country from 40,077Km^2 to 38,394 Km^2 (MOAF, 2010).

Table 1.2 : General outlook of the farming systems in Bhutan

SN	Agro-ecological zone	Altitude (m)	Temperature ⁰C	Rainfall (mm)	Farming Systems, major crops and agricultural produce.
1	Alpine	3600-4600	-0.9- 12(5.5)	<650	Semi-nomadic people, yak herding, dairy products, barley, buckwheat, mustard and vegetables.
2	Cool Temperate	2600-3600	1 - 22 (10)	650-850	Yaks, cattle, sheep & horses, dairy products, barley, wheat & potatoes on dry land,
3	Warm Temperate	1800-2600	1-26 (13)	650-850	Paddy on irrigated land double cropped with wheat and mustard, barley and potatoes on dry land, temperate fruit trees, vegetables, cattle for draft and manure, some machinery and fertilizers used.
4	Dry Sub-tropical	1200-1800	3-29 (17)	850-1,200	Maize, paddy, millet, pulses, fruit trees and vegetables, wild lemon grass, cattle, pigs and poultry.
5	Humid Sub-tropical	600-1200	5-33 (20)	1,200-2,500	Irrigated paddy rotated with mustard, wheat, pulses and vegetables, tropical fruit trees.
6	Wet Sub-tropical	150-600	12-35 (24)	2,500-5,500	Irrigated paddy rotated with mustard, wheat, pulses and vegetables, tropical fruit trees.

Sources: (a) http://foodsecurityatlas.org/btn/country/availability/agricultural-production, (b) Katwal, T. (2013)

Note: Data within parenthesis under temperature column represents mean value, while the lower and upper data represent minimum and maximum temperature

In Bhutan, two main types of cultivated land exist, locally known as Kamzhing and Chhuzhing. Kamzhing is a sloping unbunded terrace where rainfed crops like maize, potato, millet, buckwheat etc are grown (Photo 1). In recent years, Kamzhing are also being used for growing perennial fruit trees[4]. At lower altitude, maize is the predominant Kamzhing crop followed by wheat and buckwheat, while at higher altitude (above 2500 m), potato is the main crop grown in Kamzhing (Dorji, K.D. 2008).

Chhuzhing is a levelled bunded terrace where a summer crop of paddy is grown (Photo 2). Chhuzhing can be irrigated or rain-fed[5]. In English, Chhuzhing are also referred to as wetland.

Photo 1:Kamzhing (slopping field)

Photo 2: Chhuzhing (contour terraces)

Of the several crops grown, paddy (rice) is the most important and preferred food crop in Bhutan. The production of paddy is also synonymous to food security, one of the most important national goals. As a result, prevailing policies and local legal system also prohibits conversion of Chhuzhing into other forms of land uses

4 Though farming in Bhutan is largely subsistence oriented, cultivation of mandarin oranges and areca nuts at lower altitudes and apples at higher altitudes are increasing as major cash crops

5 Under irrigated condition, rice is cultivated up to an elevation of 2,600 m (Dorji, K.D. 2008).

Paddy is usually followed by wheat or some other winter cash crops. In some areas, a second crop of paddy (summer paddy followed by winter paddy) is also grown, though the area coverage by winter paddy is nominal[6]. At higher altitude, low winter temperature restricts the second crop. At lower altitude, unavailability of water and other socio-economic factors constrain the growing of a second crop. JICA (2012) notes that despite of having favourable climatic conditions; farmers in southern foot hills hesitate to grow winter crops due to fear of getting them damaged by wild animals. Rural urban migration, cheap import of food crops from India, and poor agricultural support services are other socio-economic constraints. As a result, overall cropping intensity in Chhuzhing is quite low[7], which amounts to about 110 % in three southern districts (JICA, 2012).

1.2 An overview of irrigation development in Bhutan

Until recent past, irrigation development in Bhutan was the result of farmers' own initiative and investment in the construction and management of irrigation systems, which is termed here as community managed irrigation systems (CMIS). The Government's involvement in irrigation sector started with the second five year plan in late 1960s. Since then a couple of large irrigation systems were built by the government, which are now being managed by the community. Thus, from the perspective of system management, two types of irrigation systems co-exist in Bhutan, as follows:

- Community managed irrigation system (CMIS)
- Agency built community managed irrigation systems

Irrigation system under the second category is presently limited. Some of the examples are the Taklai Irrigation System, Nganglachen-Petariin Punakha, and Lobesa Pump Irrigation also in Punakha. However, irrigation systems under this category will increase with the implementation of this National Irrigation Master Plan (NIMP).The forthcoming section presents the main features of CMIS.

Though Bhutan has a large numbers of irrigation systems, these are not presently classified under different categories. Such categorization will be useful for the planning of external interventions, system management, and research and extension support. Recognizing the need for categorization, the NIMP proposes a simple typology of irrigation systems based on their size, as follows:

Large irrigation System	With irrigated areas more than 500 acres
Medium irrigation System	With irrigated areas between 50 and 500 acres
Small irrigation System	With irrigated areas between 15 and 50 acres
Micro irrigation System	With irrigated areas less than 15 acres

1.2.1 Community managed irrigation systems (CMIS)

Farmers all over the country have developed Community Managed Irrigation Systems (Figure 1.10) based on the local agro-ecological conditions and social organization of the communities concerned. Traditions of self-governing systems and strong community participation are important factors and common features for the operation of these systems. Local ingenuity and skills have been applied over the ages to develop them. These systems contribute considerably to the Bhutan's national economy and they are the main source of livelihood for the rural community.

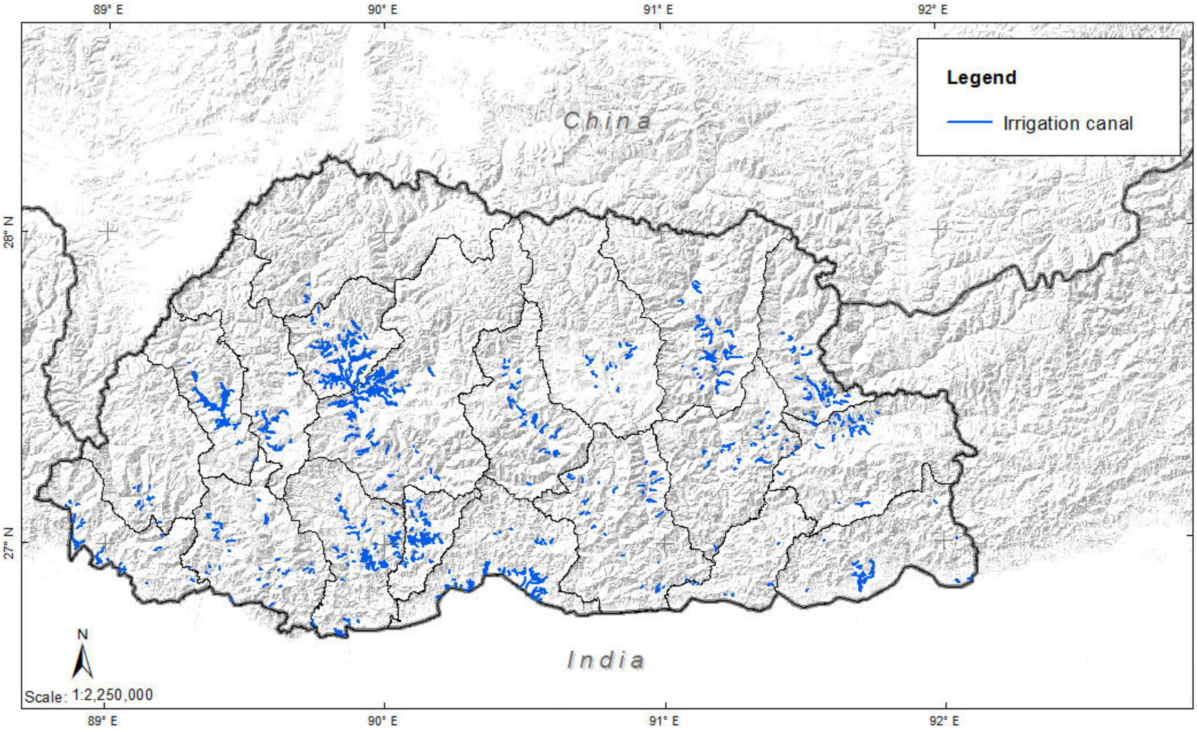
These irrigation systems are operated with very simple infrastructure built using local knowledge and skills. Canals are usually earthen. In many cases, an intake simply consists of a temporary diversion constructed across a certain stretch of river, and an ungated opening connected to the main canal. Figure 1.11 presents an example of layout map showing intakes, canals and cultivated areas of several

[6] Refer http://www.fao.org/nr/water/espim/country/bhutan/print1.stm

[7] Except in home stead areas

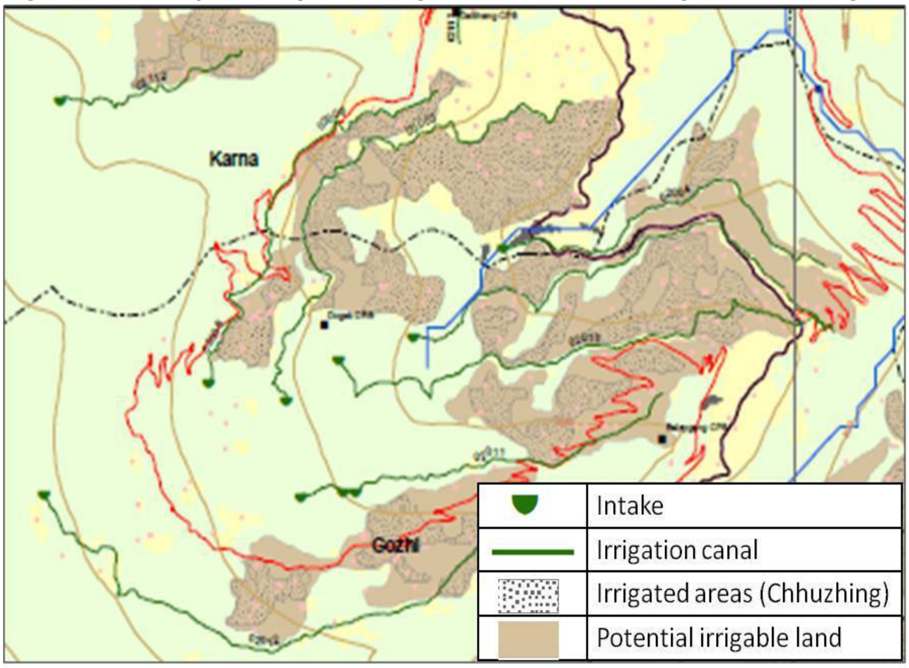
community managed irrigation systems in a mountain setting. From the perspective of maintenance needs, these irrigation systems are labor intensive.

Figure 1.10: Location of community managed irrigation systems in Bhutan



Source: ADB TA 8623

Figure 1.11 : Layout map showing intakes, canals, irrigated and irrigable areas of CMISs



Source: (DOA, 2013b)

Most community managed irrigation systems serve relatively small irrigated areas. They vary roughly between 40 and 90 acres. Systems with irrigated areas of above 100 acres are few in number.

Recent study conducted by the Department of Agriculture, has identified 1212 CMISs across the country, of which, about 851 are operational with command areas of above 15 acres. About 111 irrigation systems are dysfunctional, partly due to damages caused by rural roads and landslides, and partly due to drying out of water sources. Table 1.3 presents the status of these irrigation systems, which presently irrigate an estimated total of 64,248 acres (net) in Bhutan.

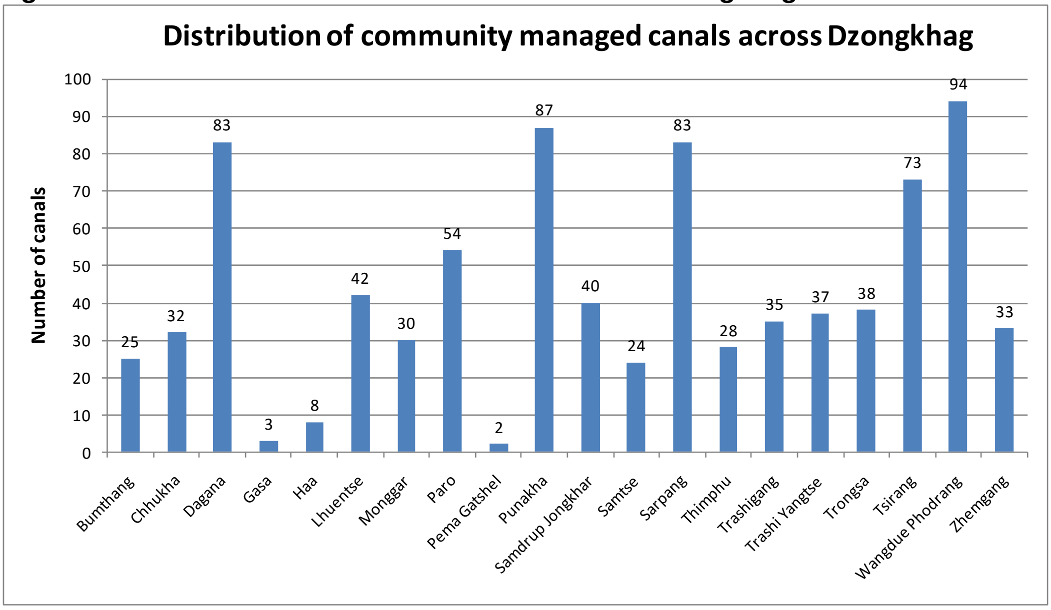
Table 1.3 : Present status of the community managed irrigation systems in Bhutan

SN	Community managed irrigation systems	No of systems	Net command area (acres)
1	Operating irrigation systems with areas above 15 acres	851	61,748
2	Irrigation systems with areas below15 acres	250	2,500
3	Dysfunctional irrigation systems with areas above 15 acres	111	
	Total	1212	64,248

Source: (DOA, 2013a)

Figure 1.12 shows the distribution of the functional irrigation systems across Dzongkhag with an irrigated area above 15 acres (851).

Figure 1.12 : Distribution of functional CMIS across Dzongkhag.



Source: (DOA, 2013a)

Figure 1.12 suggests that each of the five Dzongkhags namely Sarpang, Wangdue Phodrang, Punakha, Dagana, and Tsirang has more than 70 functional irrigation systems.

From the perspective of their geographical location, community managed irrigation systems in Bhutan can be broadly categorized into three types, as follows:

Hill schemes: Hill schemes are located on the hill slopes much higher from the rivers flowing in the deeply incised valley floor. Command areas of these schemes are relatively steep, and they are heavily dissected by natural gullies into smaller patches. In such slopes, series of levelled and bunded terraces (referred to as Chhuzhing) are well-constructed and managed by the farmers, especially for the cultivation of the monsoon paddy (photo 2). These terraces are the most striking features of irrigated agriculture in the hills of Bhutan.

The difference in elevation between the command areas and the main rivers flowing down the hills is so great that the water from the main river cannot be conveyed for irrigation. For this reason, water from the first or second order tributaries located higher up from the command areas is tapped and conveyed for irrigation. As a result, these schemes have relatively less water. Most irrigation systems found in Dagana District are typical examples of hill schemes

Valley bottom schemes: Valley bottom schemes are found on the floors of wide valleys formed by main rivers in the mid hills. Their command areas are located on the relatively wide and gently sloping river banks, which are slightly elevated from the main rivers. As diverting water from the main rivers is difficult, water is tapped from tributaries and conveyed to irrigate the command areas.

As these schemes are located at lower elevation, they enjoy relatively large and reliable flows. Depending on the elevation, two crops of paddy can be grown in these schemes. Most irrigation systems found in Punajha valley are typical examples of valley bottom schemes

Foot hill schemes: Foot hill irrigation systems are located in the southern most narrow strips of the southern foot hills bordering India and exhibit considerable differences with the valley bottom and hill schemes: foot hill schemes have relatively large and flat areas; located in lower altitude; high rainfall; unstable source rivers; rapidly changing river morphology; and frequent flash foods. So, these schemes face major challenges for diverting river water to their respective irrigation canals.

1.2.2 External assistance on irrigation, mainly CMIS

As noted above, the Government's involvement in the irrigation sector started only in 1967 (during the second five year plan) with the establishment of the then irrigation division under the Department of Agriculture. Since then the irrigation division (DOA) provided specialized attention to the improvement of CMIS through respective Dzongkhags. In those days, the focus was more on construction of bottle neck structures and maintenance support. Later, with the introduction of decentralization policy in 1981, the approach changed from construction / maintenance of the systems to institutional strengthening, including the formation of WUA (Pradhan P, 1989).

At district level, each Dzongkhag had an irrigation unit staffed with irrigation engineers, construction supervisors, draft men etc. Administratively, irrigation units were supervised by the Dzongkhags, but technically they were under the guidance of the DOA. It is estimated that during the late 1980s, the irrigation division had over 100 technical staffs (Pradhan, P 1989).

During the 5th and 6th five year plans, there were substantial external interventions in the irrigation sector. During that period a couple of large scale agency managed irrigation systems were also built, as shown in Table 1.4.

Table 1.4 : Details of earlier irrigation projects in Bhutan

SN	Name of irrigation system	Donor	Development periods
1	Gaylegphug lift irrigation system (800 ha)	India	1970s
2	Takalai Irrigation System, Sarpang district (1350 ha)	UNCDF	1988
3	Irrigation in southern Bhutan (Equipment), about 2.13 Million USD	UNCDF	5thFYP
4	Small farm development and irrigation rehabilitation (4.14 million USD)	IFAD	5thFYP
5	Chirang hill irrigation, Chirang District, South Central Bhutan (1300 ha, 3.48 million USD). The project focussed on improving irrigation infrastructure, watershed management, and agriculture support	ADB	1985-1991

6	Punakha –Wangdi Valley Development Project. It focussed on irrigation structure covering Thimphu, Punakha and Wangdi	IFAD	6th&7th plan
7	Paro Valley Project (Focus was on irrigation infrastructure)	JICA	5thto 7th plan
8	Tashigang –Mongar Area Development Project	IFAD	5th to 7th plan
9	First and second eastern zone agriculture project (EZAP). The second EZAP was 17.83 million USD. The project had five components: (i) local development initiatives, (ii) community-based natural resources development (including irrigation), (iii) renewable natural resources services, (iv) rural financial services, and (v) program facilitation and management.	IFAD	1991 to 2007

Sources: (ADB, 1985; Pradhan. P, 1989)

Besides the above mentioned interventions, several other donors like UNDP, Switzerland, and UNFP also provided technical assistance for the development of Bhutan's irrigated agriculture (ADB, 1985)

1.3 On-going irrigation development initiatives

Various irrigation development projects are currently being implemented in Bhutan. Though their approaches differ from one another, their ultimate goal is to raise the livelihood of the local communities by improving the management of natural resources. Some of the projects are described below.

1.3.1 The World Bank supported irrigation projects

1.3.1.1 Decentralized Rural Development Project (DRDP)

The Decentralized rural development project (DRDP) was initiated in 2005 with 2010 as the planned completion date. The original project cost was USD 7 million, of which USD 1.1 million was allocated for irrigation (World Bank, 2005). Originally, the project was implemented in six districts[8]covering 62 Gewogs. Later, the project was extended to cover additional five Dzongkhags (Sarpang, Samtse, Mongar, Trashigang and Punakha) with an additional funding of USD 5 million. Accordingly, the completion date of the project was also extended to December 2013.

The main objective of the project was to increase agricultural output and market access for rural communities in selected areas of Bhutan. The project had three components namely rural infrastructure, strengthening of RNR centres, and institutional strengthening. Rural infrastructure component had two sub-components: rural access and irrigation. Main activities under irrigation were to construct 45 km of new canals and to rehabilitate 231 km of existing canals.

The project was successful in achieving its targets. The closing expenditure of the project was USD 10.71 million (Nu. 482 million), of which Nu. 33 million was invested in irrigation sector. About 42.5 km of new canals were constructed that covered 678 acres of land benefiting 418 households. Similarly, this project rehabilitated about 521 km of canals of irrigation systems that commanded 11,785 acres, benefiting 4,594 households (World Bank, 2012).

The project was implemented through Dzongkhags and Gewogs as part of the decentralized development process adopted in Bhutan since the 9th FYP (2002-08). However, the Project Coordinating Unit (PCU) formed under the Ministry of Agriculture and Forests had the overall responsibility of project planning, design and coordination.

[8] Trongsa, Zhemgang, Dagana, Tsirang, Wangdue and Chukha

1.3.1.2 Remote Rural Communities Development Project (RRCDP)

The Remote Rural Communities Development Project (RRCDP) funded by the World Bank is the follow-up of the DRDP. It is being implemented since November 2012, and is expected to be completed by May 2018. The project has three components:

- Component A: Rural Infrastructure which includes rural accessibility and irrigation
- Component B: Community, marketing and productive infrastructure which include (a) establishing community and marketing infrastructure and (b) improving productive assets of existing producer groups.
- Component C: Project management and institutional strengthening.

The project area covers 26 selected Gewogs of six Dzongkhags namely Samtse, Haa, Chhukha, Trongsa, Dagana and Wangue. The total project cost is USD 9.52 million of which USD 2.7 million allocated to the irrigation sub-component.

The irrigation sub-component includes five activities:

i. Irrigation infrastructure rehabilitation and modernization (20 canals, total length 60 km)
ii. High efficiency irrigation development
iii. Water storage structures
iv. Engineering support, and
v. WUA training and support

Of the above five activities, the first three activities relate to the development of infrastructure. Table 1.5 presents Dzongkhags wide development targets of the irrigation sub component.

Table 1.5 : Planned irrigation systems under RRCDP

Irrigation sub-components	Unit	Dzongkhag						Total
		Samtse	Chhukha	Haa	Trongsa	Wangdue	Dagana	
Irrigation infrastructure rehabilitation and modernization	No.	2	2	4	4	2	6	20
	Km	21	5	9.2	7.3	3.5	14	60
High efficiency irrigation development (sprinkler, drips)	Ha	15	15	-	-	-	-	30
Construction of water storage structure (tank irrigation)	No.	1	1	1	1	1	1	6

Source: (MOAF, 2014)

The project implementation modality is similar to that of the DRDP. Unlike the DRDP however, the Engineering Division of DOA has the responsibility of a central Project Coordinating Unit (PCU). At the level of Dzongkhags, the district agricultural officer is responsible for coordinating the project activities while the Dzongkhag engineering division is responsible for technical guidance and implementation. At Gewog level, agricultural extension officers are the field implementers and reporters.

Of the targeted development of 20 irrigation systems (Table 1.5), the rehabilitation of 5 irrigation systems started in the fiscal year 2014-15.

1.3.2 IFAD Projects

The International Fund for Agriculture Development (IFAD) is providing assistance to the Royal Government of Bhutan for the agriculture sector since 1990s, most of which focusing on the eastern zones of the country. The on-going IFAD project (2011- 2015) named as “market access and growth intensification project (MAGIP)” also focuses on six eastern districts[9]. Its main goal is to reduce poverty

[9] Six eastern districts are Lhuentse, Trashi Yangtse, Trashingang, Mongar, Samdrup-Jonkhar and Pemagatshel

and improve food security and standards of living of targeted rural households. The total cost of the project is USD 13.5 million, of which the RGoB shares about USD 2 million.

The project has three main components and a number of sub-components:

i. Support to poor subsistence farming communities
ii. Agriculture intensification and support to market access
iii. Project management and coordination

Of the above three components, the second component "agriculture intensification and support to market access" has a subcomponent on infrastructure development which contributes to the following:

(a) Capacity enhancement of MOAF in planning and development of irrigation systems
(b) Rehabilitating of existing irrigation systems and expansion of small area
(c) Enhance capacity of members of Water Users Association

Furthermore, the project also provides support in the preparation of inventory of irrigation systems, the identification of new irrigation areas, the rehabilitation existing irrigation systems to cover about 400 ha of land, and the construction of new irrigation systems with targeted area of 20 ha (IFAD, 2010).

The project is still ongoing and its outcome is yet to be evaluated

1.3.3 Indian Government funded projects[10]

The Government of India (GOI) provides both technical and financial assistance in the irrigation sector[11]. GOI provides most of its assistance through budgetary grants, which are implemented following the project implementation rules of the RGoB. Table 1.6 provides details on some of the major grants provided to the irrigation sector

Table 1.6 : Summary of irrigation systems under GOI funding

SN	Plan period	Name of Grant	Project
1	10th FYP	Small Development Project (SDP) Grant	Three batches of SDP were implemented which included mainly renovation of existing irrigation canals
2	11th FYP	Project Tied Assistance (PTA)	Fiscal year 2013/14: • Rehabilitation / construction of about 20 irrigation systems • Land development in six Dzongkhags, and • Development of micro irrigation systems in 12 Dzongkhags
3	11th FYP	Project Tied Assistance (PTA)	Current projects (to be completed by the FY 2015/16): • Construction of new irrigation systems (17 numbers, 287.83 million Nu) • Rehabilitation of existing systems (3 numbers, 40 million Nu) • Land development: Terracing, fuel for machines, and spare parts (6 schemes, 3 million Nu) • Micro irrigation (12 Systems, 30 million Nu)

Source: Engineering Division, DOA (unpublished information)

[10] Refer: http://www.indianembassythimphu.bt/pages.php?id=77
[11] The first irrigation project implemented under GOI assistance is Gelegphug Lift Irrigation Project which was constructed in 1970s (Refer Table 1.4)

1.3.4 Japan International Cooperation Agency (JICA) funded projects

JICA is one of the important donors for the development of irrigation in Bhutan. Some of the recent JICA interventions include the following:

- Study: Strategic agricultural water supply and management in Southern Bhutan, 2012
- Modernization of the Taklai Irrigation Project: It is the largest irrigation system in Bhutan, which was first developed by UNCDF in 1984. The system was then severely damaged by successive floods. In 2013, JICA initiated modernization works with a grant assistance of 630 Million Nu (JICA, 2013). The project was completed in April 2015 and was handed over to DOA for system operation and maintenance.

Most of JICA projects are implemented on turn-key basis.

1.4 Present state of agriculture and national economy

1.4.1 Agriculture, national economy and policy shift

Agriculture in Bhutan is both subsistence oriented and labor intensive. But, it is one of the most important sectors of the Bhutanese economy[12]. It contributed for around 15% of GDP in 2010, while its contribution to GDP in 2002 was about 25% (Figure 1.13). Presently, it accounts for 4.3% of country's export, provides a large proportion of raw materials for industries, and directly employs about 59.4% of the total population (GNHC, 2014).

Paddy, maize, and wheat are the main cereals crops cultivated in Bhutan. Paddy is the chief staple food grown mostly under irrigated condition. Maize is mostly cultivated in dry land under rain-fed condition. Other cash crops are potatoes, chili, oilseeds, pulses, apples, and areca nut. The production of these crops has increased and has become more profitable in the recent past.

The primary goal of agriculture development in Bhutan is to: (a) raise the per capita income of people living in rural areas, (b) enhance self-sufficiency in staple crops, and (c) increase the productivity per unit of farm labor and agricultural land. However, agriculture development is constrained by several problems described in the following sections.

1.4.1.1 Planned development of agriculture sector

The planned development of the agriculture sector in Bhutan began in the 1960's with the first five year plan (1961). Development activities were supported by several programs which were managed by the then Ministry of Agriculture and Forestry. The program continued to be supported during the successive five year plans.

A significant institutional change took place since the onset of the 9thFive Year Plan (FYP) (2002-2008). Development tasks were devolved from the centre to the Dzongkhag and further down to the Gewog levels. This devolution also influenced decision-making and financial powers.

Along with this institutional change, the 9th FYP also changed the country's development outlook. Unlike the earlier FYPs, the 9th FYP hardly focussed on the agriculture sector. As a result, the share of the total development budget allocated to agriculture declined from 15.6% and 15.7% over the 6th and 7th FYPs to 10.1% over the 9th FYP (MDG, 2007). In terms of capital budget, the 9thFYP allocated only 2,000 million Ngultrum to the entire Renewal Natural Resources (RNR) sector[13] (Ref: 9thPlan, Table 4, pp53), compared to the 8th FYP allocation of 2,400 million Ngultrum only for the agriculture sector. However,

[12] Other important sectors of the Bhutanese economy are: production and sale of electricity, construction, industries, tourism, and services.

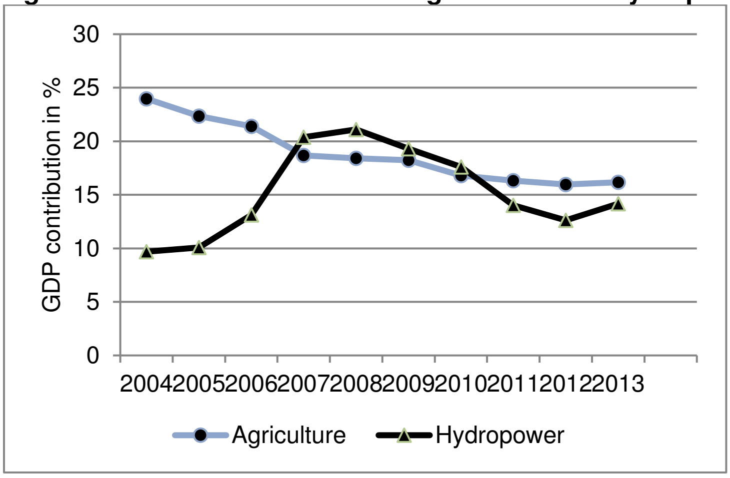
[13] The RNR sector includes sub-sectors on agriculture, livestock, and forestry

the enhancement of food security and rural economy continued to remain core development objectives. On the infrastructural side, focus was more on farm road and other rural infrastructures such as domestic water supply, buildings, trails, wild animal fence etc.

The investment decline in the agriculture sector in the 9th FYP was influenced by a powerful school of thought that promoted the concept of rice import rather than self-production. This school argued that Bhutan being a small country could manage food security by importing rice from the neighbouring country, India principally. It was further argued that rice can be imported using the revenue earned through the export of hydro-electricity[14].

As a result of this policy shift, the agriculture sector grew only by an average 1.3% during the 9th FYP period against the planned growth rate of 2.5%. In contrast, the hydropower sector grew by 36% annually over the same period (GNHC, 2009a). Figure 1.13 compares the contribution of the agriculture and hydropower sectors to national GDP between 2004 and 2013.

Figure 1.13 : Contribution of the agriculture and hydropower sectors in % to national GDP



Source: RMAB (2014)

Figure 1.13 suggests that in 2007 the agriculture sector was surpassed by the hydropower sector for the first time as the most important contributor to the national economy. This large growth is mainly due to the enhanced tariff revisions for electricity exports and that revenue generation from the Tala Hydro-electric power project (GNHC, 2009a).

In 2008, Bhutan went through a situation of food shortage (Egis, 2014) and at that time there was a crisis of the Indian Rupees as well for importing food stuff (DOA, 2013a). While at the time the situation was resolved through significant amounts of foreign aid, the risk of another food crisis in the country could not be ruled out (Egis, 2014). This situation has created a sense of urgency for the government to revitalize its policy of food security with much greater commitment. In the meantime, it was also realized that the country cannot be prosperous without the development of the agriculture sector, because it is the only sector that can provide employment to rural population through a value addition process (production, processing, marketing, etc.). Present mode of hydropower development in Bhutan however does not contribute much to employment in the rural areas as the electricity produced is mainly exported to India. Greater employment from hydropower development would be possible if electricity was to be used locally for industrialization. This is not the present policy thrust however.

With this realization, the country re-embarked on the policy of food security since 2008 / 2009, which is continuing during the on-going 11th Five-Year Plan (2013 – 2017). Present focus of the 11th FYP are on: ensuring food and nutrition security, increasing levels of national food self-sufficiency, and increasing

[14] Meeting note dated 16 September 2014, meeting with Mr. G. B. Chettri, Director, DoA, Adapting to Climate Change through IWRM, ADB TA-8623 BHU, Bhutan, September 2014

income through improved management of arable, horticulture crops and medicinal plants. Particular emphasis is given to those crops which are important for achieving food and nutrition security. With this plan / vision, investment in the agriculture sector is increasing. The tenth and eleventh FYPs provided capital budget of 3,626 and 3,966 million Ngultrum respectively to this sector, which is about 80 and 98 % higher compared to the Ninth FYP capital budget. However, the pace of development is very slow. In 2013, contribution of the agriculture sector to GDP was about 16.18 % as compared to 15.96 % in 2012.

Forthcoming section describes the production trends of some of the main cereal crops in Bhutan.

1.4.2 Production trends of major crops in Bhutan

Figure 1.14 through 1.19 presents yield, cropped area, and production of paddy, maize, and wheat since 2005 (RNR statistics, 2012; DOA AS, 2012 & 2013).

Figure 1.14 :Paddy yield

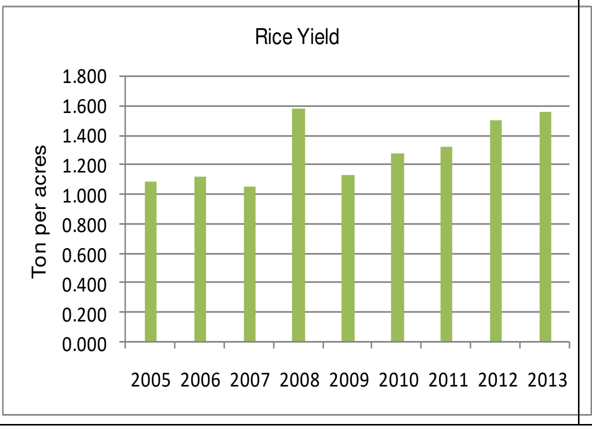


Figure 1.15 : Cropped area & production of paddy

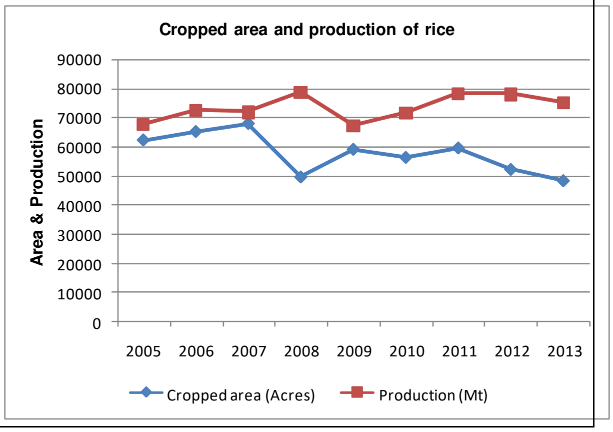


Figure 1.16: Maize yield

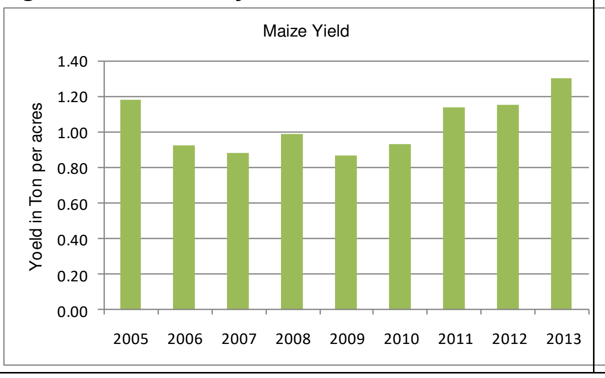


Figure 1.17: Cropped area & production of maize

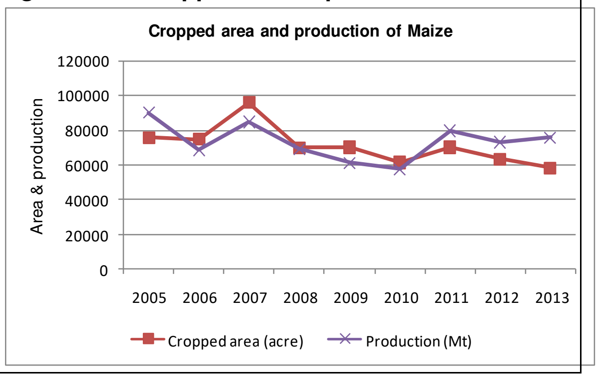


Figure 1.18: Wheat yield

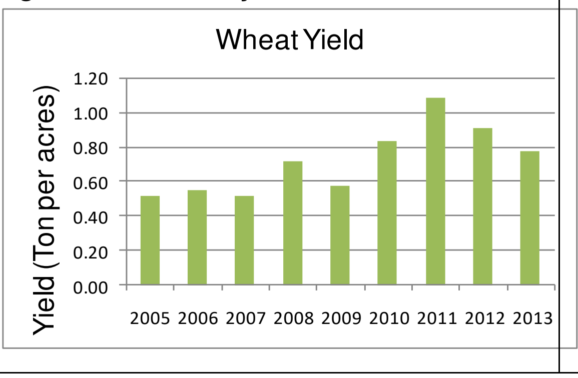


Figure 1.19: Cropped area and production of wheat

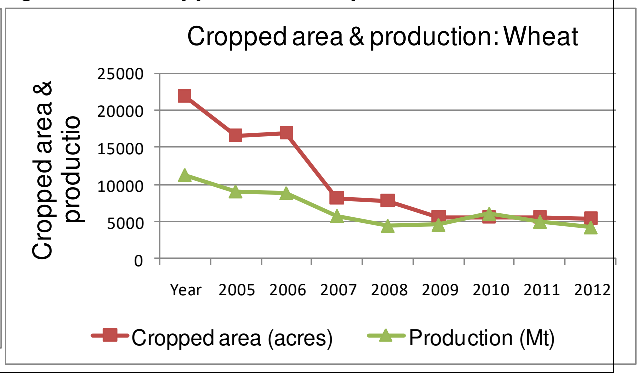


Table 1.7 describes the production trend of these crops

Table 1.7 : Production trend of Paddy, Maize and Wheat

Crop	Production trend
Paddy	• Cropped area declined from 62,360 acres in 2005 to 48,361 acres in 2013. Percentage decline in cropped area is about 23 %. • Despite the decrease in cropped area, annual production of rice remained fairly stable between 70,000 to 80,000 Mt. This is mainly due to gradual increase in yield (1.08 Mt/Acre in 2005 to 1.55 Mt / acre in 2013)
Maize	• Cropped area declined from 75,800 acres in 2005 to 58.338 acres in 2013. Percentage decline in cropped area is about 25 %. • Annual production of maize also declined gradually from 89,950 Mt in 2005 to 75,715 Mt in 2013 (16 %), while its yield increased from 1.18 to 1.3 Mt/acres (about 10%)
Wheat	• Cropped area declined rapidly from 21,900 acres in 2005 to 5,560 acres in 2010 (75% decline). Thereafter, it remained fairly stable (slightly over 5,500 acres) • Accordingly, wheat production declined rapidly between 2005 and 2010; but it tends to be stable (along with yield) between 2010 and 2013

Besides cereals, substantial land area is also cropped with high value crops like potato, chili, pulses, mustard, ginger, cardamom and other vegetables. Similarly, perennial fruit trees of citrus, apple and areca nut etc. are also becoming more popular. Unlike cereals, the cropped area and production of these crops are increasing (DOA AS, 2012 / 2013 and NSB, 2013 / 2014).

1.4.3 Crop production contribution to GDP

The foregoing section suggests that the cropped area and production of the main cereal crops are declining, while the area and production of high value crops are increasing. Figure 1.20 compares percentage growths, which is positive for high value crops and negative for cereal crops. Likewise, Figure 1.21 presents their respective contribution to crop sector GDP.

Figure 1.20 : Production growth of major crops

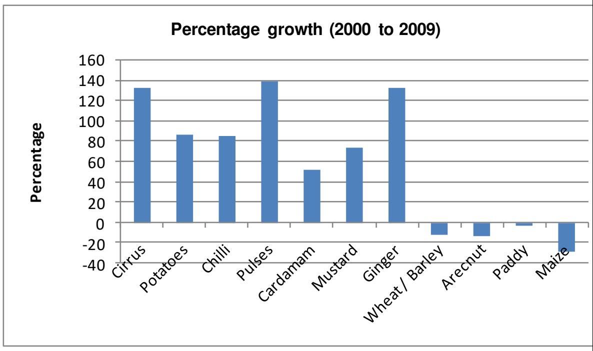
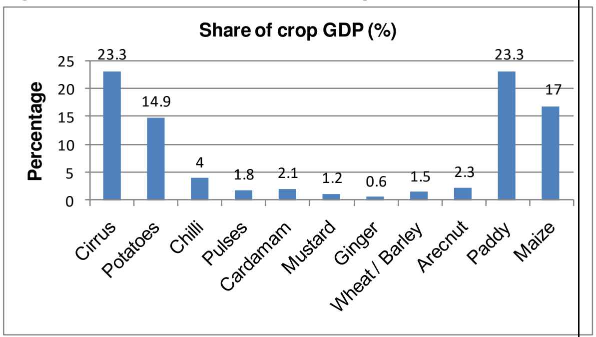


Figure 1.21 : Contribution to crop sector GDP



Source: Christensen, G. et al (2012), GNHC (2014)

Figure 1.21 suggests that the four most important crops in terms of contribution to crop sector GDP and subsequently to national GDP are citrus, paddy, potato and maize. Surprisingly, citrus and paddy have the same level of contribution, about a quarter, to the crop sector GDP. This is followed by potato and maize.

1.4.4 Main challenges causing dismal performance of the agriculture sector

1.4.4.1 Lack of irrigation and weakening public sector irrigation development capacity

Irrigation water is one of the main inputs for agriculture development. But, as of now, public investment for irrigation development has remained almost unnoticeable. Whatever irrigation that exists in the country is essentially the result of farmer's own initiatives and investment. This aspect has already been discussed the preceding chapters.

Further, with the institutional change that took place since the onset of the 9th FYP (2002-2008), district level irrigation engineering units that were technically supervised by the DOA, were merged into a single rural development engineering sector in the Dzongkhags. Irrigation engineers who were trained and experienced in irrigation design and management were diverted to several other sectors like rural roads, domestic water supply, building construction, and so on. As a result, the institutional capacities of irrigation sector that was gained during earlier FYPs were lost. Also, the country has been lacking up to now of systematic plans for the development of irrigation sector. This aspect is dealt separately under Chapter 1.5.

1.4.4.2 Declining areas under crop cultivation

Declining area under cultivation is one of the main reasons for the poor performance of agriculture sector. Cropped areas of paddy, maize and wheat have declined by 23%, 25% and 75% respectively within a period of 8 years (Figure 1.15, 1.17 and 1.19). Likewise, only 75% and 71% of the existing irrigation potential[15] has been utilized for paddy cultivation in 2012 and 2013 respectively

This means that fallow land has gradually been increasing over the last 10 to15 years. As a result the country's cultivated land is said to have been decreasing from 7.9% in 1995 to 2.9% in 2010 (Figure 1.9).

1.4.4.3 Labor shortage for agricultural activities

There is a wide recognition that farm labor shortage is one of the main reasons for declining areas under crop cultivation (mainly cereals). This is mainly due to rural-urban migration, and the process is continuing[16]. The 2005 population census of Bhutan made following observations on rural-urban migration (PHCB, 2005)

- The rate of rural - urban migration in 2005 remained as high as 51% of the urban population.
- The rural population grew at an annual rate of only 0.6% from 1985-2005 compared to an urban population growth rate of 6.1%
- About 70% of the population live in rural areas, while the urban population accounts for remaining 30%
- Nearly 60% of migrants were male, and mostly from age group of below 35 years old.

The data presented above show some of the underlying causes that create labor shortage in the agriculture sector.

However, unlike the above noted labor shortage, the 11th FYP indicates that the total agricultural workforce in 2010 has increased by 10% compared to a decade earlier (GNHC, 2014; Christensen, G. et al, 2012)[17]. This means that there may not be an actual shortage of labor in terms of its total size; the shortage seems to be more on the category of young male workers that are required for some specific

15 Presently, irrigation facility exists in about 64,248 acres of land

16 http://bhutanobserver.bt/1323-bo-news-about-rural_to_urban_migration_keeps_increasing_.aspx noted that 0.6 % of the population migrated from rural to urban areas in 2012

17 Christensen, G. et al (2012) however notified that this estimation on the increase in agricultural workforce was made based on the limited available information on rural labor markets.

agricultural activities. It is to be noted that the high rate of rural-urban migration of young males has changed the gender and age balance in rural areas, which in turn added additional burden to women, older and aged members of the family (Sharma, P.K. et al 2013). The increased dependency on women labor and aged members of the community in the rural areas is a direct consequence of the shortage of young male workers who are migrating to urban areas for better jobs (Christensen, G. et al, 2012).

The recent social and gender study conducted under the ADB TA 8623 suggests the possible following consequences of rural-urban migration in the agriculture sector (TA 8623 R6, 2015).

- It may lessen pressure on land which in turn may reverse trends towards smaller plots and the fragmentation of landholdings.
- It may help to diffuse the forces that give rise to landlessness and sharecropping arrangements. On the other hand, land consolidation would facilitate greater mechanisation and increased agriculture productivity. This may enable commercialisation of agriculture, from which higher farm incomes may derive.
- The wage for unskilled agriculture labor has increased in the recent past, and may go higher in the future.
- This will offer a positive stimulus to agricultural development and will be instrumental in raising the cash incomes of farmers

1.4.4.4 Low agricultural productivity, crop depredation by wildlife, and cheap import from India

As already mentioned, agriculture in Bhutan is based on a low input low output production system. It is primarily a mono cropping system with an average cropping intensity of slightly above 100 %. As a result, large tracts of farm land are kept fallow during the winter and spring seasons.

The production of cereal crops is constrained by the difficult terrain that reduces the scope for large scale farm mechanization, and thus agriculture in Bhutan is labor intensive. However, the meager returns for farm labor and the extremely hard manual work involved in traditional farming has contributed to the steady shift of agriculture labor to non-agriculture sectors and fuelled the growing rural-urban migration trend (MDG, 2007)

Additionally, crop depredation by wildlife is a serious threat to production. It is to be noted that crop damage by wild animals was ranked first by farmers when they were asked to state their main constraints in agricultural production (Christensen, G. et al, 2012).

Cereal crops are mostly produced for on-farm consumption. Production of surplus for the domestic market is discouraged by the low-priced imports of cereals (mainly rice) from India (Christensen, G. et al, 2012)[18]. It is to be noted that about 50% of Bhutan's rice demands are imported from India, which is sold in Bhutan at much lower prices compared to the Bhutanese rice due to the lower production costs and higher productivity in India. Table 1.8 below presents the production costs of some of the Bhutanese agricultural commodities and the average retail prices of the imported commodities.

[18] There exists a bilateral free-trade agreement between Bhutan and India that allows duty-free imports of all food and agricultural commodities (World Bank, 2011). So, mechanisms to influence food prices in Bhutan are limited.

Table 1.8: Cost of production and average retail prices of some of the commodities

SN	Commodities	Average cost of production of Bhutanese commodities (Nu/kg)	Average retail prices of imported commodities (Nu / kg)	Remarks
1	Rice (middle mountain areas)	43	40-50	Mid quality
2	Rice (Southern Districts)	29	40-50	Mid quality
3	Maize	16	21	
4	Potato	11	6	
5	Beans	24	10	
6	Onions	22	16	

Source: DOA data (unpublished report on cost of production, 2012)

1.4.4.5 Poor agricultural support services

The agriculture sector cannot be prosperous without appropriate support services. Efforts to develop agriculture in Bhutan lack support in the following areas:

- Poor access to credit at household level. Besides commercial banks, Bhutan does not have rural banks for facilitating credit to rural population at discounted rate,
- Country's subsidy policy is poor to address issue of cheap import of agricultural products from the neighbouring countries, India in particular,
- Private sector involvement in the agriculture sector is not promising due to high investment risks in this sector, and
- No policy support for facilitating seasonal labor migrations from India and Bangladesh to meet peak agricultural labor demands[19].

1.4.4.6 Climate change and impact on Bhutan's agricultural system

In recent years, climate change has also posed serious challenges to agricultural production. As three forth of Bhutan's cultivated area depends almost entirely on monsoon rain for crop production, impact of climate change on the country's overall agricultural production is likely to be negative. Further, almost all the existing irrigation systems are of run-of-the-river types, which are considered to be less resilient to climate change. In this sense, even irrigated agriculture production may be impacted by climate change. This aspect is dealt separately in the forthcoming chapter.

1.4.5 Opportunities for agriculture development

Despite the above noted challenges, there are opportunities for the development of the agriculture sector in Bhutan, as summarized below:

- Presently, there exists a high level of political commitment in the country for the growth of the agriculture sector. This is reflected in the on-going 11th five year development plan.
- Development of the agriculture sector is potentially viable, as existing cultivated land resources are underutilized. This offers substantial opportunities for expansion of agricultural production and investment. Further, a large portion of farm land is kept uncultivated during the winter season due to a prevailing mono cropping practice. This could be put under cultivation with provision of adequate

[19] Current labor policy impose restriction on employment of low-wage migrant labor from other countries in agricultural production

facilities for irrigation, farm labor, working capital, market access support, and crop protection against wildlife.

In addition, existing barren government reserved forest land could also constitute a resource for commercialized production of high value crops as provisioned by the existing Land Act.

- As indicated in Chapter 1.4.3 above, some progresses have already been achieved in the development of vegetable and horticultural crops. This could be further encouraged with adequate support services.
- Bhutan has already initiated an agricultural mechanization program. Increased role of female labor on agricultural activities due to shortage of young male labors appears to be a major factor for initiating agricultural mechanization. This will also reduce the cost of cultivation which in turn will help Bhutanese agricultural products to compete with the Indian imports.

1.5 The Department of Agriculture and its present capacity

1.5.1 Organization, staffing and irrigation planning set-up

1.5.1.1 Organization

The Ministry of Agriculture (MoAF) has four departments responsible, respectively, for (i) agriculture (DOA), (ii) forest and park services (DoFPS), (iii) livestock (DoL), and (iv) marketing and cooperatives (DAMC). Irrigation development activities are undertaken under the Department of Agriculture.

There are, in addition, four non-departmental units set up under the Ministry, namely (i) the Bhutan Agriculture and Food Regulatory Authority (BAFRA), (ii) National Biodiversity Center (NBC), (iii) Information and Communication Services (ICS), and (iv) the Rural Development Training Center (RDTC).

Research and development support to the MoAF departments and other units is provided through an inter-ministerial Council for Renewable Natural Resources (RNR) Research, whose Secretariat is based in the MoAF.

Through these various units, the MoAF undertakes the following functions:

- To develop agriculture, livestock and forest for the benefit of the Bhutanese people through continuous research and development process;
- To raise the living standard of rural people through the promotion of income generating agro-based enterprises, reduction of drudgery and improvement of nutrition and health, access to services, market and information;
- To protect the country's natural environment through the sustainable and judicious use and management of its land, water, forest and biological resources;
- To ensure food safety through preventive and mitigation measures including quality control of all RNR based consumer products and regulatory measures; and
- To represent the interest of the rural people of the country in the functions of the government.

Under the MoAF Department of Agriculture, the Engineering Division is tasked with planning and implementing irrigation development projects throughout the country, as well as providing support to the engineering staff working under the district-level administrations. The division has three engineering units, one for rural road construction, one for building construction, and one for irrigation. The location of the Engineering Division in the Department of Agriculture and its organizational setup is described in Chapter 10

1.5.1.2 Staffing

Out of the 442 staff in DOA, 24 are assigned to the Engineering Division. Most have civil engineering backgrounds. Out of these 24 engineering division staff, 15 are working in the central office—a chief engineer who heads the Division, 4 executive engineers, 2 deputy executive engineers, 4 assistant engineers, and 4 junior engineers. Nine other engineers are posted in three regional offices which provide support to district administrations (3 staff are posted in RDC Bajo, 2 in Bhur, and 4 in Wengkar).

DOA activities related to irrigation system development and maintenance are supported in the field through an agricultural machinery center, located in Paro, which is being assisted by JICA through the provision of equipment (mainly excavators and backhoes). The Paro agricultural machinery center currently has hand-driven tractors, grain threshers and other small farm equipment. According to the Chief of the Engineering Division, JICA assistance is being sought in order to acquire additional equipment.

At each district (Dzongkhag), there is an engineering unit responsible for designing and implementing various kinds of engineering projects, including irrigation works. However, the kind of irrigation works that are undertaken directly by the district administrations are limited to maintenance and repair of irrigation systems and headworks. The planning and development of new irrigation systems, including major rehabilitations, are undertaken at the central level through the DOA Engineering Division.

1.5.2 Arrangements for irrigation planning and implementation

During the preparation of the 11th Five-year Plan (FYP), the intention was for the district administrations to become responsible for identifying, planning and implementing irrigation projects, with the DOA Engineering Division mainly expected to provide planning guidance and technical support. This set-up was supposed to be a continuation of the devolution of rural development tasks from the central to the local level, which had been initiated in the 9th FYP. Under the devolution set-up, the earlier-existing district irrigation engineering units which were directly supervised by the DOA were merged with other district-level engineering staff to create a single engineering unit in each district, and supervised directly by the district administration.

As noted elsewhere, the previously specialized district irrigation engineers were diverted to other concerns such as road and building construction. It is not surprising, therefore, that capacity to plan major irrigation works at the local level has diminished considerably, and irrigation initiatives at the local level are confined to system repair works instead of new system development.

It appears, however, that towards the latter part of the 11th FYP implementation, there has been a shift in irrigation development approach—under which major irrigation projects are now being centrally planned and executed.

1.5.2.1 Existing irrigation priorities and works

Renovation of the existing irrigation systems and construction of new irrigation systems and intakes to tap additional water sources are the current irrigation priorities. Under the current FYP implementation (up to 2018), and taking into account the Engineering Division’s human resource capacity, 108 priority irrigation systems were selected for improvement and rehabilitation so as to increase the cropping intensity and to irrigate high value crops.

By 2015, thirteen of the 108 selected systems were already funded.

At the local level, the district administrations also initiate their own irrigation improvement works. These, as earlier noted, are limited mainly to canal repairs and maintenance. For donor funded irrigation projects that support local governments, such as under the World Bank/IFAD project on irrigation and farm-to-market infrastructure improvement, the DOA Engineering Division assists the local governments concerned in undertaking field surveys and provides technical design advice. In the case of irrigation infrastructure improvements, the local governments identify the sites, but the planning itself is done by the DOA Engineering Division.

1.6 Existing irrigation water users association (WUAs) and their present roles

In irrigated paddy areas, WUAs have been in existence since the time the irrigation systems were constructed (or rehabilitated) by the DOA. As part of its irrigation development policy, the DOA requires users of an irrigation system to form a water users association before the system is turned over to them. There are good examples of functional irrigation WUAs in Bhutan, especially in the South (e.g., Samtse). Seven to 8 households would typically comprise a WUA for an irrigation system of about 20 acres, but larger irrigation system WUAs also exist, even though many of them operate informally, particularly in the South.

Although the DOA has aimed to standardize the set-up of WUAs and their operating rules, in practice this is not the case. Most WUAs that have been formed to manage irrigation systems operate informally, and arrangements for cooperating on canal repairs and for contributing to a maintenance fund are governed by customary rules, rather than codified by-laws. In a survey of irrigation systems (with command areas of at least 15 acres) which was carried out under a World Bank assisted project in 2013, only 218 of the 962 systems surveyed were managed by formal water users associations governed by codified by-laws.

According the Engineering Division Chief of the DOA, there appears to be no real need for rigid rules to govern the organization and functioning of WUAs. Customary unwritten arrangements for cooperating on water use for irrigation are apparently already effective in most cases.

Customary practices apply on arrangements for allocating water among users as well as for resolving water allocation conflicts. Water use conflicts in irrigation systems arise mainly during the planting season, and these conflicts are generally resolved through arbitration by the Gups (Gewog chiefs) or village leaders.

According to the 2014 Water Regulation (Chapter III), WUAs are expected to formulate and enforce their own rules for managing and protecting water sources. This non-rigid approach reflects the observations that customary water management arrangements and non-codified community rules are already effective in managing irrigation water allocations and system maintenance, including conflict resolution.

However, such customary practices may only be effective as long as the irrigation systems remain under the traditional management practices. If external intervention to support an expansion or modernization of irrigation development is envisioned, as proposed in the NIMP, the establishment and operation of WUAs may need to be more formalized and codified. This is especially true if organized irrigators desire in future to tap micro-financing (e.g., from the Bhutan Development Bank) to procure farming equipment or inputs.

2. NIMP: Rational and methodology

2.1 Rationale for NIMP for Bhutan

Only about 276,522 acres (2.9% of the country's land area) is cultivated, of which about 28,469 acres is under orchard (permanent tree crops), about 76.880 acres (28%) constitute Chhuzhing, and the remaining 171,174 acres (62%) are Kamzhing. Different types of crops like paddy, wheat, maize, potatoes, chilli, etc. are grown. The agricultural sector is fragmented and there is no national master plan yet. Most of the farms are less than one hectare in size and farmers have few resources. As already mentioned previously, agriculture production in Bhutan is presently based on a low input - low output system. It is the result of weak public policies, budgetary constraints, and lack of pertinent administrative procedures.

Open channel is the dominant irrigation technology solely designed for paddy cultivation. Most irrigation systems are seasonal in nature. As a result, average irrigated cropping intensity is only slightly above 100%. Management aspects of irrigation have received very little attention so far from the government.

A significant institutional change took place since the onset of the 9th Five Year Plan (FYP) (2002-2008).Development tasks were devolved from the centre to the Dzongkhag and further down to the Gewog levels. This institutional change also reshaped the country's development outlook. Unlike the earlier FYPs, the 9th FYP hardly focussed on agriculture sector.

In 2008, Bhutan went through a difficult food crisis. While at the time the situation was resolved through significant amounts of foreign aid, the risk of another food crisis in the country cannot be ruled out. As a result, Bhutan adopted a policy of food-security, which aims at achieving food self-sufficiency. However, with the current agricultural model[20] and prevailing changes in socio-economic situations caused by out migration from rural areas, there is no real hope to gain macro-economic momentum for achieving food self-sufficiency.

Climate change has further aggravated the situation because three-fourth of the Bhutan's cultivated land depends almost entirely on monsoon rain for crop production. It is anticipated that economic costs associated with climate change are likely to increase in the future, if no action is taken to adapt to and mitigate its negative impact on the Bhutanese's agriculture sector.

Subsidies could be used to revive the agricultural sector, as only a very small percentage of the GDP is currently invested in irrigation and the priority for national expenditure has so far favoured health and education. While these are surely very important sectors to subsidize, irrigation is hardly less relevant than others if Bhutan wants to achieve food security, and an effective irrigation plan will ultimately benefit both the country's health and educational sectors.

Though Bhutan's economic backbone is tied to hydroelectric production, the agricultural sector cannot remain indefinitely fragmented and underdeveloped. There is a realization that while the hydropower sector has undisputed virtues, agriculture is the only sector that can provide employment opportunities to rural people so that out migration is kept in check. Thus, it is now time to boost the agricultural sector in Bhutan. This can notably be achieved by giving greater attention to crop diversification as well as to promoting the development of the irrigation sector through a National Irrigation Master Plan.

[20] Low input-low output, low incentive, influx of cheap Indian rice

2.2 Objective of NIMP

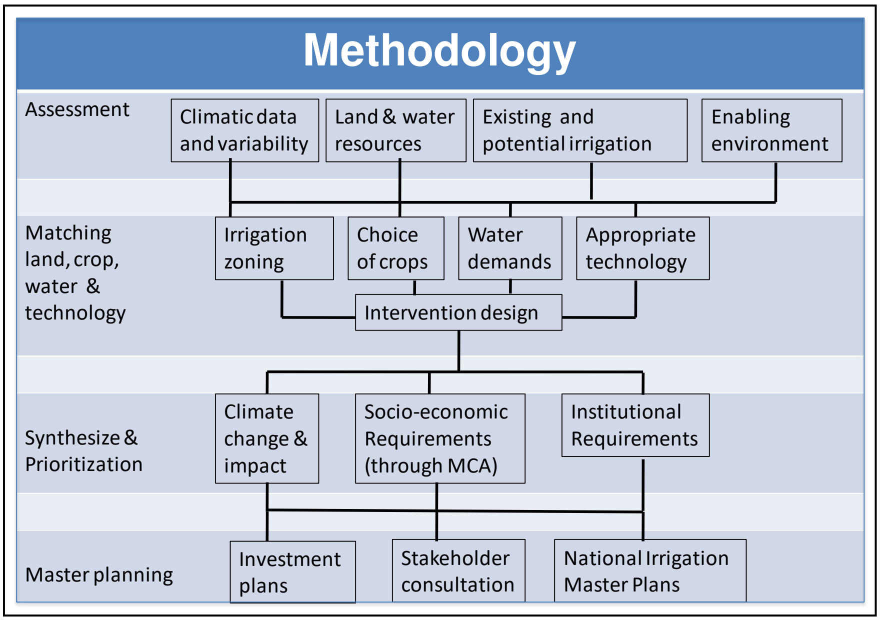
The objective of the NIMP is to facilitate the development of irrigation sector in Bhutan, so as to contribute to the broad agriculture sector's goal of reaching food and nutrition security and enhancing rural income in the country.

Chapter 14 of this document outlines excepted outcomes and outputs of NIMP

2.3 Methodology adopted for preparing the NIMP

Preparation of the National Irrigation Master plan (NIMP) followed four stages as indicated in Figure 2.1. For each stage, several participatory consultation steps were adopted.

Figure 2.1: Methodological diagram for NIMP preparation



The first NIMP preparatory stage focused on the collection of primary information and assessment of baseline situation that included climatic variability, availability of land and water resources, farming system and national economy, existing and potential irrigation, irrigation institutions, and pertinent policies. Existing and potential irrigation systems were assessed through a questionnaire survey conducted at the Gewogs' level and through field visits by professionals.

The second stage examined the primary information for matching land, water, crops and irrigation technologies. For this, the country was first demarcated into different irrigation zones based on the existing agro-ecological settings, which was followed by an analysis on the choice of crops, water demand and availability, and appropriate irrigation technologies. This second stage shaped the likely interventions on irrigation with pipeline subprojects.

The National Irrigation Master Plan was further synthesized through a third preparatory stage that examined the likely impacts on irrigation development resulting from climate change, and took into consideration socio-economic factors as well as the institutional requirements for its implementation.

The National Irrigation Master Plan proposes to prioritize the pipeline projects (subprojects) at two levels. The first level of prioritization was made based on technical considerations that resulted into an investment plan as part of the NIMP. The second level of prioritization follows a multi criteria analysis to be executed while implementing the NIMP.

The proposed investment plan under the NIMP was discussed with stakeholders through various regional and national level consultations.

Some of the key consultations conducted during the preparation of the National Irrigation Master Plan are listed below:

- Consultation on approach and methodology with concerned stakeholders (2)
- Consultation with GNH commission and other stakeholders (2)
- Consultations with the Department of Agriculture (3)
- Consultation with key stakeholders on Multi Criteria Analysis (MCA) and its indicators (1)
- Regional consultations (4)
- National level consultation for draft NIMP (1)

Besides the above, various formal and informal meetings took place with stakeholders.

3. Assessment of policies and regulatory system relevant to NIMP

There is no lack of national policies and regulatory systems for managing irrigation, agriculture, and livestock in Bhutan. All these policies are designed to support the country's overall development objectives of Gross National Happiness (GNH) that refer to peace, happiness and quality of life in more holistic and psychological terms[21]. Further, most development policies in Bhutan are pro-environment focusing more on protection and conservation of natural resources. The sections below first present assessment of relevant policies, regulatory framework, and successive five year plans. This will be followed by an assessment of policy gaps and implementation.

3.1 Assessment of Policies relevant to preparation of NIMP

3.1.1 Bhutan Water Policy (2003)

Bhutan water policy is a reflection of the Royal Government's commitment on conservation, development and management of the country's water resources. It recognizes that water is a precious natural resource and a heritage important to all aspects of social, economic and environmental wellbeing. As a result, the policy recognizes that every individual has the right to safe, affordable, and sufficient quantity of water for personal consumption and sanitation

With regard to uses of water, the water policy (2003) stipulates three main principles:

- Water is a common good. Its uses are open to all legitimate users under the provision of the water act.
- The policy sets priority for all legitimate uses of water. First priority goes to drinking and sanitation, which is essential for human survival. Allocation of water for irrigation, hydropower generation, industrial uses, recreation and other uses shall be guided based on the national and local priorities.
- The policy also recognizes the importance of water for agriculture and food production. The policy thus emphasizes that water allocation to the agriculture sector must be compatible with the objective of national food security.

Bhutan water policy (2003) adopts the principles of IWRM. It states that water resources in the country shall be managed based on natural river basins. Accordingly, the policy emphasizes establishing river basin based institutions for the same.

Regarding irrigation water uses, the policy stresses on increasing irrigation efficiency through applied and adaptive research. It also recommends for adopting a water pricing policy as an economic instrument for enhancing the efficiency of water uses.

[21] Official website of GNH commission (http://www.grossnationalhappiness.com/) provides more indicators of Gross National Happiness.

3.1.2 Food and nutrition security (FNS) Policy (2014)

The Food and Nutrition Security (FNS) policy was issued in 2014 by the Ministry of Agriculture and Forestry with an overarching goal of ensuring food security in the country. The policy defines food security as:

> availability of, accessibility to and proper utilization of food as well as maintaining stable conditions for these dimensions, and that it is achieved when all people, at all times, have physical, social and economic access to food of sufficient quantity and quality in-terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care.

The policy further specifies that the availability of food is not only limited to cereals. It also includes other food items like vegetables, livestock products (milk, meat, eggs etc), fruits, and oils and fats. Except in the case of some of the fruits that meet 95% of the national demand, the national production of most food commodities is insufficient to meet domestic needs.

Further defining the baseline situation of accessibility, utilization, and stability, the FNS policy 2014 stated:

> "*As almost all Gewogs are now connected by farm roads, physical access to food is increasing. However, due to constantly increasing food prices, economic access has remained a challenge.*
>
> *Regarding food utilization, national average caloric consumption exceeds 2,500 Kcal/person/day. However, in the worst-off areas this figure does not reach 1,900 Kcal/person/day against the minimum requirement of 2,124 Kcal/person/day. Further, average consumption of protein, vitamins, and minerals is even farther below than that is needed for good health.*
>
> *Stability dimensions of FNS is challenging due to natural calamities like foods, landslides, wind storms etc. and increasing food price due to global financial meltdown and rising food and fuel prices."*

The FNS policy is an umbrella policy which guides several subsector policies. One of which is the policy that shapes development of crop-subsector for ensuring food availability through national crop production system[22]. This subsector policy is the concern of the irrigation sector.

The FNS policy recognizes that the production of food from several field and horticultural crops is declining[23] in relation to increasing population trend. It thus outlines several visions for ensuring the availability of food. Followings are some such visions from the perspective of irrigated agriculture.

i. Ensure sustainable domestic food production and productivity through (a) increase in investment, (b) commercialization of the agriculture sector by promoting foreign direct investment (FDI), (c) public private partnership etc.

ii. Strengthen sustainable management of natural resources, mainly land and water for irrigation. With regard to irrigation, the policy outlines the following activities:

[22] Until then, Bhutan did not have specific policies for the development of the crop sub-sector under the broader agriculture sector. Its development was guided by the successive five year plans that focused on food security, conservation of natural resources, and enhancement of rural economy.

[23] The RNR statistics (2011) states that the domestic production of cereals is able to meet only about 60% of the total cereal demand. It ranged from 61% in 2008 to 59% in 2009, and in 2010 it reached 63%. In 2010, Bhutan had to import 20% of its domestic demand for millet, 52% for for rice and about 64% for wheat and barley.

- Prioritize investment in the development and implementation of irrigation and water management schemes through strategic partnership with associated sectors to manage water as a multiple resource and to increase cropping intensity and productivity of agriculture, horticulture and livestock enterprises.
- Develop and promote clean and sustainable water harvesting, utilization and management practices through adaptive and applied research.

Further, the FNS policy recognizes that climate change is likely to have a serious effect on the Bhutan's food production system in many ways. Gradual change in mean temperatures and precipitation patterns, and changing pattern of flash floods and high intensity rains causing damage to irrigation channels and agricultural land are some examples. FNS policy thus calls for developing and implementing adaptation and mitigation measures for longer term climate and environmental changes.

3.1.3 National Land policy (2010)

The National Land Policy (2010) provides an overall and consistent framework for sustainable use of land resources. It is an umbrella policy on land and land-based resources, and it applies to all land categories.

This policy is guided by several other development visions, policies and strategies. One of which is the Economic Development Policy (EDP) (2010). The EDP expressed the need to allow leasing of land to the private sector for large scale commercial farming and businesses. As land for such leasing will have to come from the government forest, the EDP (2010) called for such land policy. As a result, the national land policy (2010) was drafted with a provision for leasing of land to the private sector.

The National Land Policy (2010) adopts several guiding principles in managing land which include the following use based land zoning:

- Prime agricultural land, Chhuzhing (for food production),
- Urban and human settlement areas,
- Industrial areas including areas for hydropower development,
- Rural infrastructure areas and
- State forests

Further, in order to protect Chhuzhing for paddy cultivation, the national land policy (2010) restricts its conversion to other form of land uses. But, for those who own only Chhuzhing, the policy allows to convert part of the Chhuzhing in to Khimsa (residential land). If in case the Chhuzhing fall under declared prime agricultural zone, the policy recommends to provide Khimsa from state land at proximity as a strategy to save Chhuzhing.

With regard to the delineating and leasing of forest land for commercial uses, the National Land Policy (2010) states:

> *While upholding the constitutional requirement of maintaining a minimum of 60 % of forest cover, the Government shall delineate forest areas that do not provide biodiversity values nor have any implications on local ecosystem, as alienable areas to use for development purposes.*

The policy further states that such land can be leased out for commercial uses, provided they contribute to socio-economic development.

3.1.4 Irrigation policy

3.1.4.1 Irrigation policy (1992)

Bhutan's first irrigation policy was launched in 1992. It focused mainly on rehabilitation of existing irrigation systems and on their management aspects, particularly regarding the strengthening of local organizations and formalizing them as WUAs. Since then, Government assistance to the irrigation sector has followed three basic principles: meaningful farmer participation, support to WUAs, and multidisciplinary teamwork. The policy also elaborated the entire process of public intervention consisting of 11 steps (from farmers' requests to the end of construction).[24]

The 1992 irrigation policy was biased towards open-channel irrigation systems, and it focused solely on paddy cultivation. The policy failed to look at irrigation from the perspective of irrigating different crops using different technologies.

In 2002, a significant institutional change took place in the country. Since then much of the irrigation development activities have been decentralized to local governments[25]. As a result of this decentralization, the 1992 irrigation policy was revised in 2012 to provide a proper framework and direction for irrigation development in the country

3.1.4.2 National Irrigation policy (2012)

The national Irrigation Policy 2012 visualizes irrigation from the holistic perspectives of water supply and uses, and aims to develop dynamic and sustainable irrigation systems for enhancing national food security and economic growth. The policy outlined the following principles:

- Community participation for irrigation development to instill a sense of ownership of irrigation systems;
- Equitable allocation of available water ;
- Diversification of irrigation for crops grown on both Chhuzhing and *Kamzhing*;
- Assured irrigation water supply for Chhuzhing cultivation and protection of prime agriculture land;
- Optimal utilization of alternate water resources for irrigation;
- Enhance water management and productivity;
- Environmental responsibility in irrigation and drainage;
- Revitalized institutional arrangements for improved irrigation services delivery; and
- Inter-sectoral planning and management of water resources based on the principles of integrated water resources management (IWRM)

The policy aims to accelerate investment in the irrigation sector to be managed under participatory approach. It adopts IWRM principles for reliable and efficient uses of water for intensification and diversification of irrigated agriculture. It also aims to strengthen capacity of irrigation organizations starting from the Department of Agriculture to all the way down to WUAs for enabling them towards the sustainable management of the irrigation sector.

With regard to the development and operation and maintenance of irrigation systems, the policy outlines the following principles:

- The Royal Government of Bhutan will meet all costs required for the construction of new irrigation systems
- In the case of renovation of existing systems, the Royal Government of Bhutan will provide wages for skilled labor, materials, and their transportation to construction sites. The unskilled labor shall

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24 http://www.fao.org/nr/water/espim/country/bhutan/print1.stm

25 Named as DzongkhagTshogdu in Dzongkhag and GeogTshogde at the level of Gewogs

be provided by the beneficiaries based on the principle of equity and depending on their capacity to contribute.

- Routine maintenance is the responsibility of WUA.

3.1.5 Livestock Sector Development Policy (2012)

Livestock rearing[26] is an integral part of the Bhutanese farming systems mainly in producing cereal crops. The extent of their integration, however, varies with the altitude. In high altitude zones, livestock rearing (yak and mountain goats) dominates the production of cereal crops. In low altitude areas, crop production dominates the livestock rearing but they are well-integrated. Any change in one component would exert a considerable effect upon the other.

Contribution of livestock to agricultural production is three folds. Farm animals provide: (a) draught power for tillage, (b) farm yard manure for crop fertilization through the litters collected from forest for their bedding, and (c) food items such as milk, butter, cheese, meat, and eggs for home consumption and sale. In turn, the crop sector provides feeds for livestock through the production of green biomass, crop residue and cereals. Until recently, the non-food contribution of livestock (animal draught power and compost for fertilization) to the agriculture sector was not considered in the national GDP statistics.

In Bhutan, crop-livestock farming is mostly done by smallholders with an average farm size of 0.8 ha. About 90% of such smallholders own cattle, which contributed 4.1% to the national GDP in 2013 (RMAB, 2014). This figure however does not include non-food contributions of livestock. Considering the growing national demand of livestock products for food consumption (milk, milk products, and meat), ample opportunities exist in developing this sector, which in turn will help improving the livelihood of smallholders through the increase in production, generation of rural employment and marketing.

Recognizing this, the Ministry of Agriculture and Forestry issued the livestock sector development policy (LSDP) in 2012, which further calls for a comprehensive technical and institutional sector development policy. Specific objectives of LSDP are:

- to support national food and nutrition security through vigorous, demand-responsive animal-source commodity value chains, thereby contributing to the strengthening of farmers livelihoods and of rural economic development;
- to ensure sustained high productivity of biological and physical resources used, thereby enhancing health, diversity and resilience of the natural and cultural environment involved in the sector’s activities; and
- to manage the health of animals and the safety of their produce along the commodity chains, thereby minimizing the risks posed by animal diseases to both animal performance and to veterinary public health.

The policy aims to:

- Develop and promote comprehensive livestock product value chains as the national livestock sector is currently falling behind in meeting the demand for livestock products (meat, milk, milk, eggs, and fish).
- Establish and implement a comprehensive set of guidelines in support of livestock sector development.
- Enhance delivery of services to livestock sector development. This includes supply of animal feeds that encompasses supply of fodder/ forages/ crop residues/ agro-industrial by-products etc.
- Promote private sector in the livestock development.
- Promote organic livestock production.

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[26] This is done partly with the use of forest product

- Promote payment of environmental services (PES) for improved livestock-based natural resource management and utilization.
- Manage livestock related emergency risk.
- Strengthen institutional and human resource capacity in support of livestock sector development.

3.2 Assessment of pertaining laws and acts

3.2.1 Land law

3.2.1.1 The Land Law (1979)

The Land law (1979) allows all types of agricultural land to be converted to Chhuzhing but prohibits Chhuzhing from being changed into other forms of land use. This was consistent with the then Government's policy to achieve complete self-sufficiency in rice.

Land is privately registered in accordance with the Land Law which sets the maximum limit a person can own at 25 acres (10.11 ha) except for orchard and pasture where there is no limit . All non-registered land is considered as forest land, owned by the Government and subject to the Forest Act.

3.2.1.2 The Land Act of Bhutan (2007)

The Land Act of Bhutan (2007) protects Chhuzhing for sustained production of food with the allowance of 50-decimal Chhuzhing as Khimsa[27], if the landowner has no other land category. In view of the need to identify and protect Chhuzhing, the Land Act provides for zoning of land for different purposes. It maintains the provision on the upper limit on land holding of 25 acres.

The 2007 Land Act also enables commercial agriculture and enables the Government to declare any area in the country as protected agricultural area aiming at the best use of land. While the act protects Chhuzhing, those outside protected agriculture areas can be converted to other land categories if found infeasible for paddy cultivation. Conversion of Chhuzhing to residential land is permitted if land owners have only inherited Chhuzhing and do not own a house to live in.

The Act also maintains the provisions from the Land Act, 1979 that enable construction and renovation of irrigation channels and embankments as well as its right of way when passing through the property of any other person.

3.2.2 Bhutan Water Act (2011)

The Royal Government of Bhutan promulgated the Water Act (2011) to ensure that the water resources are protected, conserved and/or managed in an economically efficient, socially equitable and environmentally sustainable manner. It states that water resources are state property. The act empowers the National Environment Commission (NEC) for overall management of water resources including its implementation.

Water Act (2011) specifies that water management will be organized on an integrated river basin level, and water uses will be prioritized as below:

i. water for drinking and sanitation;
ii. water for agriculture;
iii. water for energy;
iv. water for industry;
v. water for tourism and recreation; and
vi. water for other uses

[27] Khimsa refers to homestead

The Water Act (2011) further specifies that the Ministry of Agriculture and Forest is responsible for agricultural water management that encompasses land-use and irrigation, watershed management, water resources in forests, wetland and protection of catchment areas.

It further stresses that each irrigation system will be managed by a respective Water Users Association (WUA) with self-governing rules and regulations, and such WUA has to be registered with the competent authority. Besides providing sustainable services to its uses, a WUA will also be responsible for: (a) maintaining water source and protecting it against vandalism and other damages, and (b) coordinating and overseeing the activities and management of irrigation services by its members so as to foster a sense of ownership among the irrigation users.

The Water Act 2011 provides an elaborate guideline for managing an irrigation system. The guidelines relate to: (a) principle of water allocation, (b) basis of resources mobilization for irrigation system maintenance, (c) basis of aligning a canal between two plots, (d) irrigation priorities, and so on. The water act protects irrigation in Chhuzhing. It also recognizes the customary water management practices and traditional water rights.

The Water Act (2011) also distinguishes between rehabilitation and new construction of an irrigation system. If an irrigation system has remained dysfunctional for five years, its renovation is regarded as new construction.

3.2.3 The Water Regulation of Bhutan (2014)

The Royal Government of Bhutan promulgated the country's Water Regulation in 2014 to i) enforce the objectives and purposes of the Water Act, ii) effectively implement and enforce the Water Act by the competent authorities, and iii) identify roles and responsibilities of designated competent authorities and other relevant organizations. The Water Regulation 2014 became effective from 01 January 2015

The regulation recognizes the National Environment Commission (NEC) as an apex body for developing plans and policies, coordinating with sectoral agencies and other stakeholders, and overseeing integrated development and management of water resources.

The regulation identifies ten organizations from the government and non-government sectors as key competent authorities which are responsible for enforcing respective provisions of the regulation. The Ministry of Agriculture and Forest, Local Governments, Civil Society Organizations, and Dzongkhag Water Management Committees are the key competent authorities for aspects related to irrigation management.

The Ministry of Agriculture and Forest is responsible for the development of plans, policies and programs for the management of irrigation, watershed, wetland, and irrigated agriculture. Likewise, the main responsibility of DzongkhagTshogdu lies on project implementation including monitoring and evaluation, while GewogTshogde will be responsible for managing WUA and water related database. Likewise, Civil Society Organizations will be responsible for awareness raising and capacity buildings.

The regulation makes a provision for a Dzongkhag Water Management Committee (DWMC) to ensure effective protection and management of the water resources at Dzongkhag level.

The Water Regulation (2014) also makes a provision for water users associations (WUA) to ensure the promotion of present and future water security interests at community level. Membership of the WUA will be attached to the household. The WUA will be registered with the Gewog administration unit. In a situation when households of an area are members of both the irrigation and domestic water supply systems, the same WUA will work for both the systems. Further, if an irrigation system covers two or more Gewogs, WUA will be registered with Gewog administration that has a majority of users.

Main functions of WUAs are:

- To protect and conserve water source,
- To ensure equitable and fair access to water
- To hear and decide disputes on water use
- To set water distribution mechanism
- To manage water efficiently
- To federate with other WUAs at basin , sub-basin and watershed levels
- To maintain data base of water users
- To maintain water use systems

WUA will be federated at the level of watercourse or watershed.

The regulation empowers Gewog administration with a regulatory role of water administration. So, the respective Gewog will be responsible for (a) issuing water abstraction permit from a specified location and (b) monitoring the water uses from the specified sources.

The regulation also recognizes customary water rights.

Finally, the water regulation provides an elaborate guideline for managing an irrigation system. The guideline relates to: (a) maintenance of irrigation system which will be the responsibility of WUAs, (b) principle of water allocation, (c) basis of water distribution, and (d) safe disposal of overflow from irrigation field.

3.3 Successive Five Year Plans (FYPs)

Bhutan's first five year plan was launched in 1961 with the overarching development philosophy of Gross National Happiness (GNHC: 9th FYP). Since then 10 five year development plans have been completed, and presently Bhutan is implementing the 11th five year plan.

The paragraphs below outline irrigation and agriculture related development objectives of the successive five year plans starting from the 8th plan.

3.3.1 8th Five Year Plan (1997-2002)

The 8th Five Year Plan (1997-2002) recognized the crucial role of irrigation for paddy production with a view to achieving at least 70% self-sufficiency in all major grains by 2002 (Ministry of Planning, 1996). It also aimed at crop diversification and intensification with a view of increasing Bhutan's revenue base and raising rural income[28].

The 8th FYP outlined the following three irrigation related objectives:

- to raise the productivity of existing paddy-based irrigation systems through sustainable improvements in water delivery and management;
- to increase rural incomes by diversifying the range of irrigated crops grown on both the Chhuzhing and Kamzhing; and
- to rationalize the irrigation assistance program with a view to increasing the role of water users and the private sector, and to reduce recurrent government investments in irrigation systems.

The agriculture sector performed quite well during the 8th FYP. It grew by 3.8% against the targeted growth of 2.5%. Contribution of the agriculture sector to GDP was around 34% against the planned contribution of about 31%.

[28] Source: http://www.fao.org/nr/water/espim/country/bhutan/print1.stm

3.3.2 9th Five Year Plan (July 2002 – June 2008)

A significant institutional change took place since the onset of the 9th FYP. Development tasks were devolved from the centre to the Dzongkhag and further down to the Gewog levels. This devolution also included responsibilities of decision-making and financial powers.

Unlike the 8th five year development plan, the 9th plan provided limited focus on agriculture / irrigation sectors. But, enhancement of food security and rural economy continued to remain core development objectives. In spite of this, the 9th plan hardly talked about irrigation (GNHC, 2002). On the infrastructure side, the focus was more on farm roads and other rural infrastructures.

In the 9th FYP, the agriculture sector did not perform well. It grew on an average by 1.3% against the targeted growth of 2.5%. In contrast, the electricity sector grew by 34%. As a result, the contribution of the agriculture sector to the GDP declined from 34 to about 19% by the end of the 9th FYP.

3.3.3 10th Five Year Plan (2008-2013)

The 10th FYP recognized that the low emphasis given previously on the irrigation / agriculture sector has resulted in poor agriculture growth and stagnant food production. The 10th FYP thus allocated more resources to this sector (GNHC, 2009a and 2009b)

Though the overall development objective of the 10th FYP has remained the same as before (enhancement of food security and rural economy), the plan changed its irrigation development outlook at programme level. For the first time, the 10th FYP provided focus on overall irrigation management that included exploration of alternative water sources for irrigation, and adoption of appropriate technologies to improve access to water and water use efficiency. Table 3.1 presents expected outcome, output and programme activities of the 10th FYP.

Despite some changes and innovations made to accelerate the growth of the agriculture, it did not perform well even during the 10th FYP.

The midterm review of the 10th FYP conducted by FAO / World Bank cooperative program noted that the annual growth of the crop sector remained at about 2.2% in real terms from 2000-2009 (Christensen, G. et al, 2012). Within the crop sub-sector, while the growth rate of high value crops (mainly fruits and vegetables) was high, the growth rate of main cereal crops (rice, maize, wheat) remained modest. As GDP contribution of cereal crops is high (about 40%), their modest increase in production has severely compromised the overall crop sector growth rate. The midterm review further stated that rapidly expanding rural roads and decreasing availability of labor force in rural areas have caused a divergent growth pathway between the cereal crops and high value commercial crops. Furthermore, low-priced rice imports from India have also de-motivated farmers from growing more cereal to generate market surplus.

With regard to expenditure, the Department of Agriculture (DOA) could only spend about 71.2 % of the allocated capital budget of the 10th FYP. This reflects the department's low implementation capacity.

3.3.4 11th Five Year Plan (2013-2018)

The 11th FYP (GNHC 2013a, 2013b, 2013c, and 2014) outlines the following two main irrigation / agriculture related objectives. It intends to give a new impetus to the agriculture sector through improved irrigation systems:

- to ensure food security
- to raise rural incomes through improved management of arable land, crops (cereals and horticulture), and development of agriculture infrastructure.

Recognizing the difficulties of implementing large scale infrastructure development projects through local governments, the 11th FYP proposed a two pronged approach for project implementation. The DOA will plan, design and implement all major and rehabilitation projects in the countries that includes storage and lift irrigation systems, whereas, the local governments with technical support from DOA will implement irrigation projects that are small in scope and have less complexity. The Table 3.1 presents the expected outcomes, outputs and program activities of the 11th FYP.

Table 3.1: Expected outcomes, outputs and program activities of the 10th and 11th FYP

Key Performance Indicators (Outcomes)	**Key Interventions**	**Budget** *Nu.* (Million)
10th FYP (2008-13) • Self sufficiency in rice increased from 50% to 65%, from the present level of 54,325 Mt per year to 62,474 Mt per year • Cereal production including paddy increased from 140,000 to 150,000 Mt per year • Portion of wetland with dry season irrigation increased from 40% to 70%.	(a) Renovation of Irrigation Channels in emergency (b) Renovation of Taklai Irrigation Channel (c) Water Harvesting & Irrigation of cash crop (d) Drip & Sprinkler Irrigation Trials (e) Feasibility Study of large scale irrigation and Ground Water (f) Policy Review & Database Development (g) Establishing and Strengthening of Water User Associations	*70.5 (expenditure 71.2%)*
11th plan (2013-2018) • Paddy field area under improved irrigation system will increase from 19200 ha (47443 area in 2011) to 32,000 ha (79,072 acre) • Horticulture (cash crops) area under irrigation will increase to 300 ha(741 acre) (baseline 0 ha in 2011) • Annual rice production increase from 78,730 Mt (in 2011) to 98,894 Mt (in 2018) • Annual cereal production including rice increase from 183,333 Mt (in 2011) to 223,737 Mt (in 2018) • Productivity of rice increase from 1.3 Mt/acre to 2.0 Mt/acre • Level of food self sufficiency increased from 64% to 75%	**Outputs:** *Rice based:* • 10 new irrigation systems to be constructed • 20 existing irrigation systems to be improved • 20 reservoirs to be constructed (baseline 1) *Horticulture based:* • 20 new irrigation systems to be installed for horticulture **Activities:** • Construct new IS for rice based farming, improve existing irrigation infrastructure, construct water storage structure (paddy based) • Install new systems for horticulture • Promote and streamline the effective functioning of WUA, Develop irrigation water allocation system in the country, Study on soil moisture regime post & pre-monsoon, renovation of irrigation system through community contract, develop guideline / manual for NIP implementation, disseminate & implement NIP guidelines, develop & update national irrigation database, pilot implementation of lift pump irrigation, upscale ground water harvesting for irrigation	1411[29]

Source: 10th and 11th FYP, Government of Bhutan

3.4 Gaps in policies and their implementations

The foregoing sections outline the policy provisions and successive five year plans on the development of irrigated agriculture in Bhutan. The paragraphs below present some of the main gaps in policies and in their implementation.

29 1401 million for rice based irrigation development, and 10 million is for horticulture based irrigation development

3.4.1 Food security

Food and nutritional security has been one of the important policy objectives of the Royal Government of Bhutan for many years. Though food security has been narrowly equated with food self-sufficiency in the past, it does not necessarily mean food self-sufficiency. The Food and Nutrition Security (FNS) policy (2014) defined food security as "availability of, accessibility to and proper utilization of food as well as maintaining stable conditions for these dimensions" (FNS Policy, 2014). So, guaranteeing food security means: (a) ensuring food availability either through local production or import, (b) securing access to food through enhancement of cash income of rural and urban population, (c) managing effective utilization of food, and (d) maintaining stability of the food chain.

Of the above four dimensions of food security, the two dimensions, namely, ensuring food availability through local production, and enhancing cash income of the rural population through cultivation of high value crops are the concerns of the irrigation sector. These policies thus call for year round irrigation for a diversified agricultural production, including from the livestock and horticultural sub-sectors. However, from the perspective of irrigation, production of cereals as staple food commodities and high value crops for cash income generation remains the main concern, though production of livestock feeds cannot be overlooked.

In Bhutan, as rice is the most important staple food, production of paddy has remained synonymous to food security. As a result, the successive FYPs set targets on paddy production. Table 3.2 presents these targets and achievements.

Table 3.2 : Targeted level of food self-sufficiency by different five year plans

Five year plans	Baseline value		Target			
	Year	Production	Year	Population	Production	Remarks
8th FYP (1997-2003)			2002			70% self-sufficiency in major grains
10th FYP (2008-2013)		54,325	2013	73,3004	62,474	65% of self-sufficiency in rice
11th FYP (2013-2018)	2011	78,730	2018	790,215	98,894	125 kg/head/year. Level of food self-sufficiency increased from 64% to 75%

Source: 10th and 11th FYP

The above table indicates that paddy production targets and achievements between the 8th and 11th FYPs are inconsistent. Further, the targeted production of paddy by the end of the 10th FYP (62,474 Mt) is much lower than the 11thplan baseline value (78,730 Mt). In this sense, although the policy is clear on food security and thereby production of paddy, it remains weak at implementation level.

3.4.2 Institutional overlap in water/ irrigation management

Several institutions are involved in implementing water sector policies. Some of the key institutions that are involved in the irrigation sector include the National Environment Commission, Department of Forest, Department of Agriculture, and local governments (Dzongkhag and Gewog).

Bhutan has adopted the principle of IWRM, and Bhutan Water Policy (2003) mandates the National Environment Commission for coordinating water related activities among different public sector institutions. Likewise, tasks related to irrigation development are entrusted to the Department of Agriculture. So, the Irrigation Policy (2012) mandates DOA for planning and implementing large scale irrigation systems. Similarly, the Department of Forests has the primary responsibility for planning and coordination for watershed management.

As over 70% of Bhutan is covered by forests, many of the irrigation water sources are bound to be located within forests. In such a situation, forest and related acts will be effective while building irrigation intakes inside forest area. One such act is the "Forestry & Nature Conservation Act (1995)" which prohibits blocking or diverting any river, irrigation channel, and waterfall from the forest areas.

The above policy and regulatory provisions have created a situation of overlaps in the institutional roles and responsibilities in managing water resources. There is a need to clarify these for better managing irrigation development in the future.

3.4.3 Monitoring irrigation performance

Though the Irrigation Policy (2012) recognizes the importance of monitoring and evaluation of the irrigation sector, the policy is silent on M&E indicators. Further, there is no consistency on the use of these indicators by successive FYPs. Area coverage and the length of canal built or rehabilitated were the most commonly used indicators of irrigation development until the 9th FYP. The 10thFYP introduced a new indicator as "percentage of dry season irrigation of wet land". This indicator, however, is not used in the 11th FYP.

This calls for reviewing the irrigation policy (2012) in order to define indicators for monitoring irrigation performances. The M&E framework presented later in this NIMP provides some of the recommended monitoring indicators

3.4.4 Land management for irrigation

Bhutan has a constitutional requirement of maintaining a minimum of 60 % of forest cover. So, all other land uses need to be managed within the remaining 40 % land area. In this sense, agricultural land is scarce in Bhutan. As a result, Bhutan restricts conversion of Chhuzhing into other form of land uses (Land Act, 2007; National Land Policy, 2010). Further, in order to manage the remaining land efficiently, Bhutan's national land policy (2010) aims to initiate the zoning of land for several uses.

Geographically, many of the Chhuzhing are located in the valley floors, and they are very productive. But, despite the above policy provision and regulatory framework, many of these Chhuzhing are being encroached by urbanization. As a result, existing paddy fields (Chhuzhing) are being lost. In this context, the 9th FYP notes:

> Urbanization along the valley floors and consequent loss of agricultural land is occurring at a rapid pace. Establishments of townships and other social infrastructure on agricultural land have cut into farmland.

Though there are policies and regulatory frameworks for restricting the conversion of Chhuzhing into other form of land uses, they are silent on keeping the Chhuzhing fallow. Many of the Chhuzhing where winter crops used to be cultivated in the past are now becoming fallow due to the changing socio-economic situation. As a result, irrigated cropping intensity is decreasing.

3.4.5 Gaps in Water Regulation (2014)

The Water Regulation 2014 includes a provision for Water Users Association (WUA) to manage water at the system and community level. However, it does not distinguish between irrigation and domestic water users. In situations where systems for irrigation and domestic water uses both serve the same people, a single or common water user association will work. However, such a situation usually does not exist, unless a village based WUA is formed rather than a system based WUA. In this regard, the regulations silent on the formation of sector specific WUAs (irrigation / water supply systems), when membership is different.

The regulation recognizes that household is the basis in obtaining membership of an irrigation system. This provision excludes a non-resident water user for being member of WUA. In a situation when there are substantial non-resident water users, it will be useful to include their participation in WUA. Further, with this membership criterion, a non farming person having house in the area without any cultivated land can also be a member of irrigation system. This provision looks bit awkward.

The regulation empowers Gewog administration for issuing licenses for abstracting water from a source whose point of abstraction is located within its geographical jurisdiction. In a situation when a watershed is shared by different Gewogs, each Gewog may tend to issue licenses to its water uses systems without considering water uses in other Gewogs. This approach is somewhat deviating from the concept of river basin based management of water resources. This approach also contradicts with the aim of federating WUA at watershed / basin levels.

There seems to be some institutional overlap between Gewog administration, River Basin Committee, Dzongkhag Water Management Committee (DWMC), and FWUA (federated Water Users Association) in performing several activities of water resources management. It will be helpful to further define their respective responsibilities through implementing rules.

Further, the water regulation is silent on: (a) categorization of irrigation systems for development planning, and (b) right of way of canals.

3.4.6 Mismatch between Irrigation Policy and other national plans & policies

There are some mismatches between the Irrigation Policy 2012 and other national policies including the 11th FYP, as follows:

i. Historically, irrigation in Bhutan means irrigating Chhuzhing for cultivation of paddy. Even today, this notion tends to prevail. As a result, the Irrigation Policy (2012) still focuses on managing irrigation for Chhuzhing. The policy, however, is not explicit for developing new irrigation systems for irrigating Kamzhing. In contrast, the 11th FYP targets to develop new irrigation systems with modern technology for irrigating 300 ha of Kamzhing with a view to cultivate cash crops.

ii. Though the Irrigation Policy (2012) adopts the principles of IWRM for inter-sectoral planning & management of water resources, it does not define whether irrigation is to be managed at the level of political boundary (Dzongkhag / Gewog) or at the level of river basin. This aspect will have implication in designing and revitalization of irrigation organizations in the future. Bhutan Water Policy (2003), however, explicitly adopts the principles of river basin based management of water resources. As irrigation is the major consumer of water (for consumptive uses), it will be useful if irrigation policy also explicitly adopts river basin based management of irrigation systems following the Bhutan Water Policy (2003).

iii. The Irrigation Policy (2012) is silent on private sector investment in the irrigation sector. However, other national policies are proactive on this aspect. For example, the Land Act (2007) and National Land Policy (2010) aim to lease out some of the forest areas that have less biodiversity values to the private sector for commercial uses, provided they contribute to socio-economic development. Commercial farming of high value crops, seeds, and medicinal plants are some of the possibilities. In such cases, private sector investment in irrigation is also likely.

The Irrigation Policy (2012) is silent on demarcating small versus large irrigation or simple versus complicated technologies to facilitate the sharing of intervention responsibilities between the Department of Agriculture and local governments. As the 11th FYP aims to pursue a two pronged approach for project implementation, such demarcation is needed.

4. Assessment of cultivated and potential irrigable land

The total land area of the country is about 38,394 square kilometres. About 70.5% of this area is covered with forests, while the shrubs and meadows constitute about 14.5% of the total area. Figure 1.8 in section 1.15 of Chapter 1 presents the areas for all land uses in Bhutan. The paragraphs below describe the cultivated and cultivable land areas.

4.1 Cultivated land

There is considerable uncertainty as regard to the cultivated land in Bhutan. The LUPP (Land Use Planning Project) in 1995 estimated its coverage to be 7.9% of the country's total area, while the Land Cover Mapping Project (LCMP) in 2010 estimated it to be only 2.9% (Figure 1.9). There could be several reasons for this mismatch, one of which is outlined below.

Discussions with several agricultural officers suggest that many privately owned land which were cultivated in the recent past (say a decade ago) have remained fallow for quite some time, and are now covered by natural bushes. Attentive field observations show the existence of abandoned terraces on land that have not been cultivated for years. Such land, although not cultivated at present, are certainly cultivable and possibly irrigable as well. Labor shortage is reported to be one of the main reasons for leaving land uncultivated.

LCMP definitions of cultivated and shrub land were examined in this context. They states:

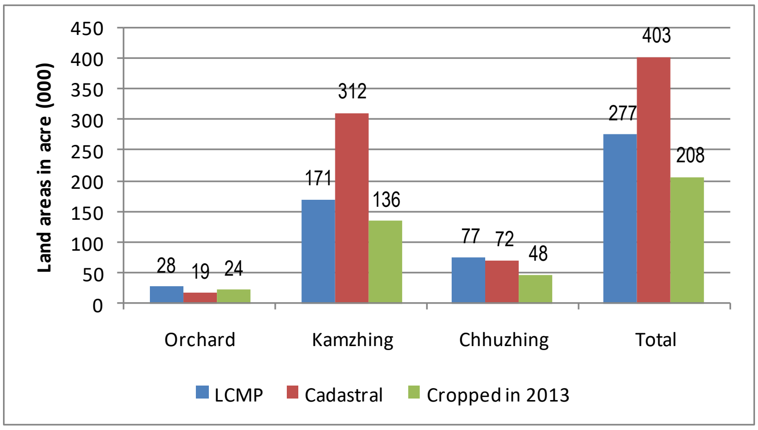
i. The cultivated agricultural land includes only those areas that were cultivated at the time of the land cover assessment.

ii. Shrub land are areas containing woody perennial plants which include natural vegetation as well as human-induced scrubland such as abandoned agricultural fields with overgrown bushes

The above definitions clearly indicate that the land that were not under cultivation or temporarily abandoned at the time of mapping were not regarded as cultivated land; rather they were considered as shrub land. This means that shrub land under this category could still be considered as cultivable and potentially irrigable.

Land areas under the LCMP and Cadastral map register were also examined in this context. Figure 4.1 shows the areas of Kamzhing, Chhuzhing and orchards recorded in LCMP and Cadastral map register, along with the actual harvested areas in 2013 as reported by DOA. Similarly, areas of Kamzhing, Chhuzhing and orchards are also presented per district in both numerical and graphical forms in Table 4.1 and Figures 4.2 and 4.3 respectively for further analysis.

Figure 4.1: Land areas of Kamzhing, Chhuzhing and orchards[30] from LCMP, Cadastral map register, and DOA



Source: MOAF (2010), Cadastral register; and DOA AS (2013)

Figure 4.1 suggests that only about 68% of the so called cultivated land as per cadastral register is being presently cultivated, of which only about 75% was harvested in 2013.

Table 4.1: Land area of Kamzhing, Chhuzhing, and orchard per district

Dzongkhag	Cadastral area (ac)				LCMP area (ac)			
	Orchard (Cadastral)	Kamzhing (cadastral)	Chhuzhing (Cadastral)	Total	Orchard (LCMP)	Kamzhing (LCMP)	Chhuzhing (LCMP)	Total
Bumthang	91	14,792	0	14,883	22	6,592	23	6,637
Chhukha	2,219	22,517	2,696	27,432	4,740	14,176	3,922	22,838
Dagana	1,932	17,305	5,511	24,748	3,597	11,338	3,691	18,627
Gasa	0	764	292	1,055	0	955	355	1,309
Haa	215	4,656	175	5,046	1,543	5,112	219	6,874
Lhuentse	0	10,302	3,558	13,860	2	10,696	3,893	14,592
Monggar	25	27,577	2,130	29,732	8	13,098	1,079	14,185
Paro	603	10,969	3,912	15,484	2,530	8,787	4,358	15,675
Pemagatshel	2,296	29,690	615	32,601	828	11,953	204	12,985
Punakha	96	3,687	8,953	12,736	41	647	12,488	13,177
Samdrup J	630	28,395	2,550	31,576	616	16,634	2,836	20,086
Samtse	4,631	26,542	8,968	40,141	8,732	20,140	14,041	42,913
Sarpang	4,072	14,856	5,765	24,694	2,280	8,283	4,791	15,355
Thimphu	576	4,102	749	5,427	2,229	2,258	1,132	5,620
Trashigang	49	35,534	4,999	40,583	0	12,312	3,557	15,869
Trongsa	131	7,485	2,800	10,416	0	2,977	2,674	5,651
Tsirang	1,522	10,527	4,700	16,749	777	7,085	3,775	11,636
Wangdu	59	5,894	7,171	13,124	0	4,878	9,920	14,798
Yangtse	0	15,822	3,600	19,423	0	5,220	2,340	7,560
Zhemgang	334	20,293	2,681	23,307	522	8,033	1,580	10,136
Total	19,482	311,710	71,825	403,017	28,469	171,174	76,880	276,522

Source: MOAF (2010); Cadastral map register (computed by TA 8623)

Table 4.1 suggests that land areas as per cadastral map amounts to 403,107 acres that corresponds to 4.25% of the country's land area. Whereas, land areas as per LCMP map amounts to only 276,522 acres that account for 2.91% of the country's land areas.

30 2013 cropped areas under orchard are not available. It is therefore assumed to be the average of LCMP and cadastral register.

Figure 4.2: Areas under Kamzhing as per LCMP and cadastral register

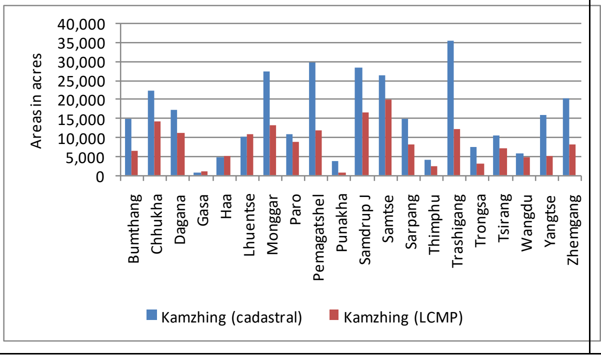
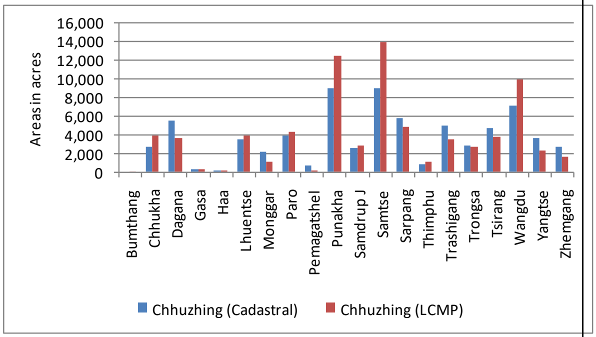


Figure 4.3: Areas under Chhuzhing as per LCMP and cadastral register



Source: ADB TA 8623 (areas computed using land use and cadastral maps)

Further, the examination of Figures 4.2 and 4.3 indicates that in all the Dzongkhag, the Kamzhing areas recorded in the LCMP are less than those recorded in the Cadastral register. This tends to suggest that privately owned land under Kamzhing that used to be cultivated in the past are not any more cultivated at present. Such deviations between the Cadastral map register and the LCMP are not seen for Chhuzhing except in the case of Punakha, Samste and Wangdu Districts.

4.1.1 Distribution of cultivated land across agro-ecological zones

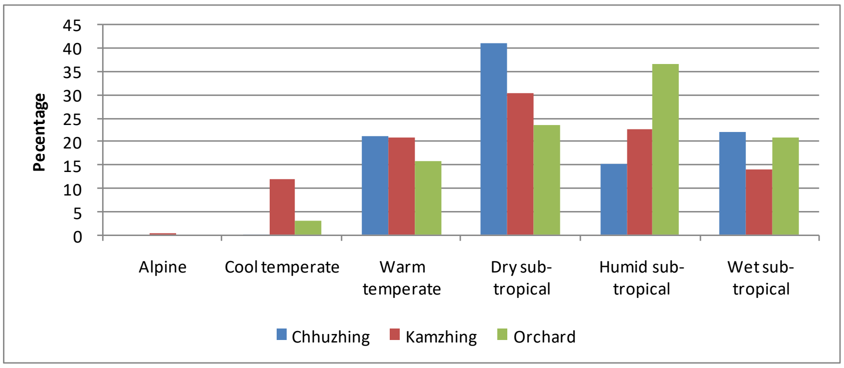
Total land areas under Chhuzhing, Kamzhing, and orchards measured as per LCMP are further distributed according to agro-ecological zones in Table 4.2. Similarly, Figure 4.4 presents a summary of this distribution in a pictorial form.

Table 4.2: Land areas under Chhuzhing, Kamzhing, and orchard

Agro-ecological zones	Land areas in acres				Percentage land areas
	Chhuzhing	Kamzhing	Orchard	Total	
Alpine	0	586	0	586	0.21
Cool temperate	24	20,211	872	21,107	7.6
Warm temperate	16,344	35,742	4,533	56,619	20.5
Dry sub-tropical	31,728	51,919	6,736	90,383	32.7
Humid sub-tropical	11,798	38,526	10,406	60,730	22.0
Wet sub-tropical	16,984	24,190	5,922	47,096	17.0
Total	76,878	171,174	28,469	276,520	100.00

Source: ADB TA 8623 (areas computed using land use maps of LCMP)

Figure 4.4: Percentage distribution of Kamzhing, Chhuzhing, and orchard land areas per agro ecological zones



Source: ADB TA 8623 (areas computed using LCMP land use maps)

Table 4.2 and Figure 4.4 suggest:

- The dry sub-tropical zone has the highest percentage of cultivated land amounting to 32.7% of the total. This is followed by the humid sub-tropical and warm temperate zones that contain 22% and 20.5% of the cultivated land respectively (Table 4.2)
- Over 40 % Chhuzhing are found in the dry subtropical zone. This is followed by 22% in the wet subtropical zone and 21% in the warm temperate zones (Figure 4.4).

4.2 Potential irrigable land

An irrigable land is a land that is suitable for irrigation, and where water can be transported from a source for irrigating the crops grown on it. Thus, factors that need to be considered for deciding "irrigability" of a land include soils, climate, topography, water resources, infrastructure and also the socio-economic situation of the community living in the area. Sometimes, a piece of land may be suitable for irrigating high value crops with the new irrigation technology, while the same piece of land may not be suitable for irrigating other crops with a more conventional irrigation technology.

Thus, it is necessary to evaluate the irrigation system as a whole including the natural and socio-economic conditions of the land, and not just the characteristics of soil. The suitability of soils for irrigated crops is essential information but it is not sufficient for making decisions about land use development.

Theoretically, all cultivable land are irrigable provided that irrigation is performed with an appropriate technology without hampering the local bio-physical environment, and that crops can be grown with economic viability. In reality, however, such ideal conditions are not often encountered, especially for irrigating cereals. Thus, in absence of appropriate data for deciding "irrigability" of a land unit, it is safe to assume that 50% of the cultivable land could be irrigated. It can therefore be assumed that the potential irrigable land is Bhutan is about 200,000 acres.

4.3 Summary

The above considerations lead to following conclusions:

Areas that are actually cropped in 2013:	208,000 acres	Ref Figure 4.1
Present cultivated land in the country:	276,522 acres	Table 4.1 (following LCMP data)
Cultivable land in the country:	403,013 acres	Table 4.1 (following cadastral data)
Potential irrigable land:	200,000 acres	Assumed (see above)
Present irrigated area:	64,248 acres	Table 1.3

It is to be noted that the above mentioned cultivable and subsequently potential irrigable land may further increase if public land is found feasible for commercial farming following the Land Act of Bhutan 2007.

5. Assessment of water availability and irrigation demands

5.1 Assessment of water availability

5.1.1 General

Bhutan is endowed with enormous water resources draining 2,238 m3/sec annually. Precipitation and surface runoff are the main sources of water. Availability of water from these sources is discussed below.

5.1.1.1 Precipitation

In Bhutan, especially at altitudes above 5000m a.s.l., precipitation occurs mostly in the form of snow, which contributes largely to the surface runoff of major snow-fed rivers, mainly during the summer season. The contribution of snow and glaciers to the major rivers is, however, difficult to quantify. Table 5.1 presents average monthly rainfall (long term average) observed through the 20 class A stations established in Bhutan.

Table5.1: Average monthly rainfall observed

Station\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bhur	16.8	31.6	81.4	256.2	445.2	1045.9	1334.2	1006.6	649.2	204.4	16.1	11.2	5098.9
Chamkhar	5.5	11.3	31.5	64.2	89.1	104.1	149.6	141.4	93.2	62.3	5.2	2.3	759.6
Dagana	10.9	35.3	43.2	106.1	204.8	349.3	345.9	336.7	282.5	124.5	8.2	5.8	1853.3
Damphu	9.9	15.6	37.2	67.0	114.2	276.2	404.6	294.4	180.2	88.2	4.4	5.9	1497.6
Deothang	13.4	36.3	92.2	285.7	453.4	869.7	826.9	540.1	418.9	164.5	15.0	7.5	3723.7
Gasa	20.4	29.9	66.8	80.9	145.1	248.8	361.5	290.5	159.3	111.9	31.2	11.0	1557.4
Kangma	10.9	24.1	48.6	102.8	119.9	192.8	249.5	216.1	120.8	75.8	4.8	4.8	1171.0
Lhuntse	5.6	30.9	37.6	76.7	120.0	94.1	158.0	144.2	83.7	83.6	14.4	2.5	851.3
Mongar	5.3	12.8	35.8	82.0	94.6	135.7	189.5	161.6	110.1	73.2	3.1	3.0	906.7
Namjeyling	12.1	16.5	29.7	54.4	73.3	126.8	180.9	173.1	123.9	68.3	2.6	4.1	865.7
Paro DSC	8.6	12.7	20.8	32.3	58.4	84.6	174.3	114.8	89.9	51.3	9.2	4.0	660.9
Pemagatshel	12.8	32.0	92.7	130.9	167.4	327.2	458.2	286.8	187.7	121.1	21.7	9.8	1848.4
Phuentsholing	17.8	31.9	76.3	218.8	390.3	859.9	915.5	757.9	434.9	161.0	12.8	11.6	3888.5
Punakha	15.3	25.2	14.7	45.1	89.7	147.0	154.7	146.7	95.7	45.4	4.3	3.9	787.6
Simtokha	6.5	10.2	16.6	26.9	48.2	98.7	145.2	126.9	67.5	45.2	1.7	3.9	597.4
Sipsu	21.3	43.3	95.3	338.9	609.1	1062.0	1297.5	1065.1	661.8	217.3	28.6	16.9	5456.8
Trashi Yangtse	10.7	24.8	52.0	99.5	130.5	174.1	224.0	217.9	149.5	71.1	13.0	4.8	1171.7
Trongsa	8.5	16.8	49.7	104.2	153.0	183.7	237.9	231.9	148.0	71.1	8.5	6.5	1219.9
Wangdue	8.4	9.7	16.7	42.6	62.8	106.6	144.1	136.1	92.0	45.7	6.8	3.6	675.0
Zhemgang	12.5	22.9	44.5	70.4	133.1	242.7	319.8	225.8	181.8	81.0	7.3	6.9	1348.6

Source: DHMS (Department of Hydrological and Meteorological Services)

5.1.1.2 Surface runoff

Bhutan has an extensive river system, which is broadly categorized into two groups: (a) the main rivers that flow north-south, and (b) their tributaries that flow from east to westerly directions. These river systems form 10 hydrological basins (Figure 1.5), which have been grouped into 5 *management* basins from the perspective of water resources management (TA 8623 R1, 2016). Table 5.2 presents their areas and annual flows in MCM.

Table 5.2: Drainage areas and annual flows of Bhutan's river basins

Hydrological Basin (Figure 1.5)				Management basins		
SN	Name	Area (km2)	Annual flow (MCM)	SN	Name	Area (km2)
1	Jaldakha	942	9,375.07	1	Amochhu	3252
2	Amochhu	2310				
3	Wangchhu	4596	5,209.06	2	Wangchhu	4596
4	Punatsangchhu	9645	19,129.79	3	Punatsangchhu	11582
5	Aiechhu	1937	6,989.14			
6	Mangdechhu	7380	11,797.24	4	Mangdechhu	7380
7	Drangmechhu	8457	13,569.14	5	Drangmechhu	11584
8	Nyera amari	2348	4,506.57			
9	Jomori	642				
10	Merak-Sakteng	137				
	Total	38394	70,576.01			38394
	Flow (m3/sec)		2238			

Source: ADB TA 8623

Table 5.2 suggests that the total water yield of Bhutan is 2238 m3/sec or 70565 MCM per annum. Further details on the Bhutan's water resources can be found in the ADB TA report on Modeling and Assessment of Water Resources of Bhutan (TA 8623 R7, 2016).

5.1.2 Water availability for irrigation

Water availability is first assessed at the level of existing irrigation systems for further developing them. This is followed by an assessment of water availability at the level of each district / basin for developing new irrigation systems.

5.1.2.1 Assessment of water availability for improving existing irrigation systems

A recent study conducted by the Department of Agriculture has listed existing irrigation systems with command areas above 15 areas (DOA 2013a). The study examined the status of water availability in these irrigation systems by using four qualitative indicators.

- Abundant,
- Adequate,
- Inadequate, and
- Acute shortage

The qualitative indicators listed above are not precisely defined. It is not known where the survey was made for assessing water availability at the level of irrigation system or at their sources. Nevertheless, Table 5.3 presents the water availability assessment for the existing irrigation systems.

Table 5.3 indicates that 86% of the existing irrigation systems draw water from perennial water sources (river or streams), while 14% of them depend on seasonal water sources. So, 86% of the irrigation systems can operate round the year.

Likewise, about 30% of the irrigation systems are said to have abundant water supply, 41% have adequate water, 20% have inadequate supply, and 9% have acute water shortage.

Table 5.3: Assessment of water availability for existing irrigation systems

SN	Dzongkhags / Districts	Number of irrigation systems with:					
		Water sources		Water availability			
		Perennial	Seasonal	Abundant	Adequate	Inadequate	Acute shortage
1	Bumthang	27	0	7	10	6	2
2	Chhukha	35	7	20	11	2	1
3	Dagana	89	18	22	34	19	12
4	Gasa	3	0	1	0	2	0
5	Haa	7	3	1	3	6	0
6	Lhuentse	34	5	13	18	9	4
7	Monggar	31	1	9	11	6	4
8	Paro	54	3	13	22	17	2
9	PemaGatshel	7	2	1	0	2	4
10	Punakha	88	3	24	34	20	10
11	Samdrup Jon.	35	8	17	13	6	5
12	Samtse	26	12	8	13	5	3
13	Sarpang	64	44	41	33	12	12
14	Thimphu	29	1	14	9	4	1
15	Trashigang	34	3	8	14	12	3
16	TrashiYangtse	49	5	15	21	4	0
17	Trongsa	25	2	6	19	11	5
18	Tsirang	73	12	23	42	13	2
19	Wangdue	111	7	19	49	22	7
20	Zhemgang	29	8	10	16	6	2
	Total	850	144	272	372	184	79
	In percentage	86	14	30	41	20	9

Source: (DOA, 2013a)

This suggests that about 71% of existing irrigation systems have either abundant or adequate water supply. These systems can be further improved so as to increase their irrigated area and/or cropping intensity. Likewise, water availability in about 29% of the existing irrigation systems is either scarce or inadequate. These systems can thus be strengthened only through source diversification provided such sources exist. Appendix A1 presents the long list of irrigation systems that have abundant or adequate water supply.

5.1.2.2 Assessment of water availability through hydrological models

Several hydrological models have been used in assessing water availability at district and basin levels, of which WEAP (water evaluation and planning) is one such model. Detailed results on water availability can be found in the TA water modelling reports (TA 8623 R7, 2016). Table 5.4 presents monthly water availability in MCM per district.

Table 5.4: Monthly water availability in MCM per district

SN	District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (MCM) / Yr
1	Bumthang	63	63	112	251	304	359	659	701	432	308	108	61	3,422
2	Chukha	116	183	164	247	449	1,455	2,356	1,671	1,384	597	180	131	8,933
3	Dagana	42	45	62	88	138	356	614	478	425	238	58	43	2,587
4	Gasa	79	62	55	193	380	772	1,050	941	630	398	180	114	4,854
5	Haa	73	92	145	295	489	950	1,441	1,049	851	406	96	78	5,963
6	Lhuentse	54	68	150	343	369	597	833	812	613	344	103	55	4,342
7	Mongar	52	67	89	220	244	410	674	480	427	258	76	46	3,042
8	Paro	21	25	30	57	71	105	181	183	126	103	40	30	971
9	Pema Gatshel	65	95	69	157	233	732	1,212	834	728	327	99	63	4,614
10	Punakha	23	28	34	54	118	221	316	303	210	116	39	26	1,488
11	Samdrup Jo.	31	54	14	28	78	344	584	435	376	166	61	36	2,207
12	Samtse	27	34	7	20	71	336	471	323	331	143	53	24	1,841
13	Sarpang	53	103	17	42	122	515	973	761	617	279	105	65	3,651
14	Thimphu	33	37	48	90	139	247	392	383	260	180	68	45	1,921
15	Trashi Yangtse	37	45	88	200	258	423	534	499	392	207	79	48	2,810
16	Trashigang	58	104	78	203	247	637	1,069	789	636	336	92	56	4,305
17	Trongsa	29	49	77	196	259	409	647	516	393	356	51	28	3,010
18	Tsirang	21	25	32	63	92	229	400	303	289	125	32	24	1,634
19	Wangdi	21	19	31	81	166	292	354	298	221	125	39	27	1,673
20	Zhemgang	71	94	106	231	329	571	1,001	778	595	314	88	48	4,227
	Total	969	1,293	1,408	3,056	4,557	9,958	15,762	12,536	9,938	5,324	1,647	1,049	67,496

Source: ADB TA 8623

Basin and district level assessments of water conducted through river basin modelling suggest that 3 months of the year, namely January, May and June are critical from the perspective of water demand and availability (TA 8623 R7, 2016). Recognizing this, water availability assessments were made for these three particular months. Table 5.5 presents 80% dependable water availability (for present and 2030 scenarios) after deducting all the present and future water uses other than what would be required for future irrigation.

Table 5.5: 80 % dependable water availability per district for three critical months (January, May and June)

Sl No	District	M3/sec		
		Jan	May	June
1	Bumthang	22.5	59.3	95.6
2	Chukha	33.5	117.7	419.3
3	Dagana	13.5	20.5	79.5
4	Gasa	29.0	31.2	65.1
5	Haa	20.7	110.5	223.7
6	Lhuentse	19.2	74.0	163.6
7	Mongar	18.9	51.6	106.8
8	Paro	6.3	15.2	23.7
9	Pema Gatshel	20.9	57.3	212.9
10	Punakha	7.5	21.0	54.3
11	Samdrup Jongkhar	9.3	23.1	106.0
12	Samtse	7.1	20.1	103.4
13	Sarpang	14.0	33.0	157.9
14	Thimphu	7.6	24.2	38.4
15	Trashi Yangtse	13.0	61.4	129.0
16	Trashigang	17.8	55.0	175.1
17	Trongsa	8.6	37.0	107.4
18	Tsirang	7.1	18.3	62.4
19	Wangdi	9.9	32.0	50.4
20	Zhemgang	25.7	57.3	137.4

5.2 Irrigation demands

Detail assessment of crop water requirement and irrigation demand per unit of land is presented through the forthcoming chapter on Irrigation Planning (Table 7.15, Chapter 7). Similarly, Chapter 12 presents a summary per district of the proposed new irrigated areas (Table 12.8).

Irrigation demand for the proposed new irrigated areas is computed based on the above data and is compared to the 80% dependable water availability for three critical months (January, May and June), as presented in Table 5.6.

Table 5.6: Irrigation demand versus dependable water availability for three critical months (January, May and June)

SN	District	Area	January			May			June		
			Duty	Water demand	80 % dependable supply	Duty	Water demand	80 % dependable supply	Duty	Water demand	80 % dependable supply
		Acre	(l/se/ha)	m3/sec	m3/sec	(l/se/ha)	m3/sec	m3/sec	(l/se/ha)	m3/sec	m3/sec
1	Bumthang	280	0.00	0.000	22.5	0.36	0.040	59.3	0.19	0.021	95.6
2	Chukha	913	0.56	0.205	33.5	1.36	0.504	117.7	1.17	0.430	419.3
3	Dagana	2131	0.28	0.245	13.5	1.71	1.472	20.5	2.59	2.229	79.5
4	Gasa	24	0.00	0.000	29.0	0.26	0.003	31.2	0.01	0.000	65.1
5	Haa	77	0.00	0.000	20.7	0.38	0.012	110.5	0.13	0.004	223.7
6	Lhuentse	1104	0.27	0.120	19.2	2.08	0.928	74.0	3.67	1.638	163.6
7	Mongar	885	0.28	0.101	18.9	1.95	0.699	51.6	3.03	1.086	106.8
8	Paro	976	0.23	0.093	6.3	1.88	0.743	15.2	2.92	1.154	23.7
9	Pema Gatshel	53	0.29	0.006	20.9	1.60	0.034	57.3	1.88	0.040	212.9
10	Punakha	1543	0.29	0.184	7.5	2.15	1.343	21.0	3.45	2.157	54.3
11	Samdrup Jon	1449	0.27	0.161	9.3	0.38	0.224	23.1	0.00	0.000	106.0
12	Samtse	6066	0.58	1.418	7.1	0.59	1.444	20.1	0.06	0.155	103.4
13	Sarpang	4202	0.57	0.971	14.0	0.95	1.608	33.0	0.25	0.425	157.9
14	Thimphu	676	0.27	0.075	7.6	1.93	0.528	24.2	2.92	0.799	38.4
15	Trashi Yangtse	1155	0.28	0.131	13.0	1.75	0.817	61.4	2.71	1.269	129.0
16	Trashigang	628	0.36	0.092	17.8	1.45	0.369	55.0	2.13	0.541	175.1
17	Trongsa	670	0.28	0.076	8.6	1.47	0.400	37.0	2.26	0.613	107.4
18	Tsirang	1333	0.33	0.177	7.1	1.89	1.018	18.3	2.43	1.312	62.4
19	Wangdi	1916	0.23	0.182	9.9	1.89	1.468	32.0	3.17	2.456	50.4
20	Zhemgang	919	0.27	0.100	25.7	1.72	0.640	57.3	2.38	0.885	137.4

Table 5.6 suggests that the 80% dependable water supply (available water) at the level of a district is not a constraint for developing irrigation. However, water availability at the level of the water sources concerned is not known.

5.3 Summary

- Rainfall and surface runoffs are two primary sources of water for irrigation.
- Water availability for irrigation is examined at two levels: (a) at the level of existing irrigation systems for further development, and (b) at the level of each district for developing new irrigation systems.
- 71% of existing irrigation systems have either abundant or adequate water supply. From the perspective of water availability, these irrigation systems can be upgraded for expanding their command / irrigated area and cropping intensity.
- 29% of the existing irrigation systems have scarce or inadequate water. These irrigation systems can thus be strengthened only through source diversification provided such sources are available locally
- Water availability (80% dependable) at the level of a district is not a constraint for developing new irrigation systems. However, water availability at water source level is not known.

6. Assessment of climate change and its impact on agriculture

6.1 Climate change in Bhutan

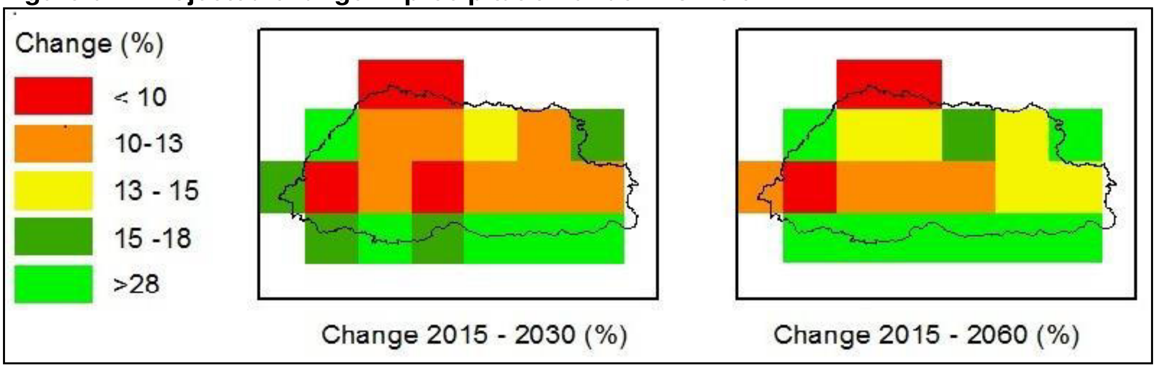
Although Bhutan is endowed with enormous water resources, climate change poses a significant risk in the coming decades. Because of its rugged mountainous terrain and wide altitudinal variations within short horizontal distances, Bhutan is unique in having perhaps the greatest variety of climates for a country of its size. This characteristic of Bhutan makes it particularly vulnerable to the adverse effects of climate change. Further, being located in the region of the Hindu Kush-Himalayas, where the warming rate has been greater than the global average (TA 8623 R5, 2016), threats due to climate change further increases in Bhutan.

Temperature and precipitation are two key climatic variables most influenced by climate change. This phenomenon is predicted to affect seasonal water availability, which could have serious impacts on irrigated agriculture[31], and consequently on Bhutan's overall economy.

6.1.1 Climate change projection

Hydro-meteorological data projections made recently by the ADB TA 8623 based on the latest climate change scenarios (CMIP5: Fifth Coupled Model Inter-comparison Project) point out a change in climatic variables with an overall increase in temperatures (TA 8623 R5, 2016).The study suggests that throughout the country rainfall is likely to increase, but with large spatial and temporal variations. This increase is projected to occur during the wet season (monsoon), whereas during the remainder of the year rainfall will not increase and may even decrease. The increase in rainfall is likely to be more pronounced in the south of the country and less in the north. Figure 6.1 presents projected change in precipitation.

Figure 6.1: Projected change in precipitation under RCP 8.5



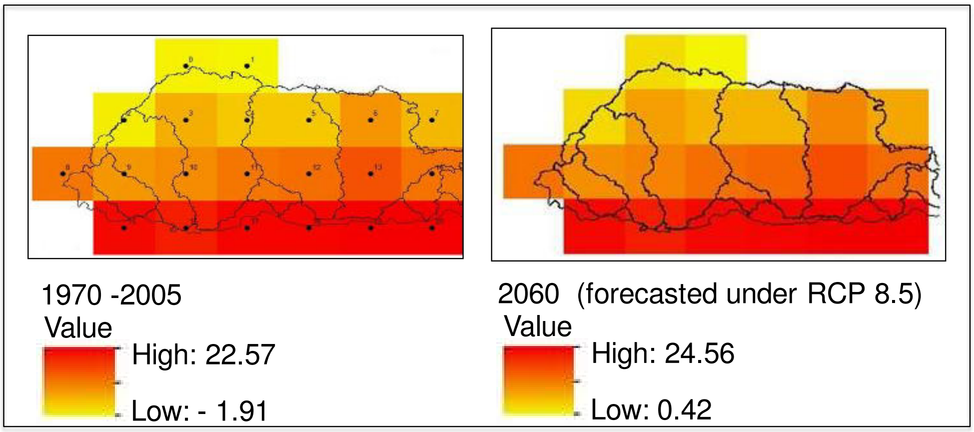
Source: ADB TA 8623

Another observation is that the projected increase in total annual rainfall is mainly on the account of greater rainfall intensity, not an increase in the number (frequency) of rainy days. In short, more rainfall is expected to occur at greater intensity.

[31] In general, although irrigation is taken as a way to reduce climatic variability, all irrigation systems in Bhutan are not resilient to climate change. This is because, most existing irrigation systems are of run-of-the river type with small water sources in which water availability depend almost exclusively on monsoon rains.

Regarding temperature, there is a consistent finding across models on a warming pattern over the country, with a greater change projected to take place during the winter season; and more so in the north of the country (TA 8623 R1, 2016). Figure 6.2 presents the projected change in mean annual temperatures between 1970-2005 historical data and 2060 forecasted data under RCP 8.5. This has an impact on river discharge by increased snow and glacial melt.

Figure 6.2: Projected change in mean annual temperature



Source: TA 8623 R5 (2016)

6.2 Impact of climate change on climatic and hydrological variability

The foregoing section presented projected changes on climatic variables (mainly temperature and rainfall) whose effects are interrelated and compounded, as changes in one variable will influence the other. For example, increases in temperature are expected to intensify the hydrological cycles, which in turn may cause more extreme precipitation events.

Climate change is likely to induce the following effects on the climatic and hydrological variables[32]

- Rainfall will be more erratic and more intense
- More precipitation will be as rainfall rather than snowfall
- Snow melt will start earlier
- Winter season will be shortened
- Number of consecutive dry days per year may increase
- As more rains are anticipated in the wet months, flood flows and transportation of sediment and debris will increase.
- In contrast, the dry season flows is expected to reduce
- Peak river flood flows may occur earlier (will shift from July-August to June-July in the future).Sometime this phenomenon is also termed as shifting of monsoon.
- Pre-monsoon river flow (May-June) may increase

The above changes will further impact irrigated agriculture. This is discussed below.

6.3 Impact of climate change on irrigated agriculture

Impact of climate change on irrigated agriculture will be of two types: direct and indirect. Likely changes in crop water demand and biomass production is the direct impact. It can be both negative and positive.

[32] Refer: TA 8623 R5 (2015); Abracosa, R. (2012); EGIS (2014)

Negative impact of temperature rise	• Evapotranspiration will increase[33] • Crop water demands will increase • Loss of some of species due to unable to adapt to rising temperature
Positive impact of temperature rise	• Biomass production and consequently crop yield will increase • Cultivation may become possible at higher altitude • The growing of new crop species may become possible

These changes will further influence agricultural production, which is described later in this section.

All the above noted changes in climatic and hydrological variables are expected to increase risks of flood, draught, storms, hail stone, lighting, heat waves etc., which in turn will indirectly impact irrigated agriculture. Table 6.1 summarizes the likely risks and their impacts on irrigated agriculture.

Table 6.1: Likely risks and their impact on (irrigated) agriculture

SN	Risks	Impacts
1	Flooding and flash floods (Due to increased and erratic precipitation and likely Glacial Lake Outburst -GLOFs)	• Physical damages to infrastructure • Inundation, and sedimentation in irrigation systems • Increased destabilization of nearby land, • Erosion, landslides
2	Change in seasonal water availability and drought	• Increased water availability (mainly in snow-fed rivers) during pre-monsoon (May June) • Reduced water availability in rivers during winter (November-March) leading to long dry spell & draught • Fluctuating water availability in rivers during the monsoon season leading to intermediate dry spell and draught • Loss of crops due to long dry spells
3	Landslides and sediment flow	• Physical damages to infrastructure, and sedimentation in canals of existing irrigation systems • Increased destabilization of nearby land • Erosion
4	Storms, hail and lightening	• Physical damage to natural and built assets, and loss of crops
5	Heat waves (Mainly in southern foot hills)	• Crop losses, forest fires, damage to physical infrastructure through expansion /cracking (e.g. pipes), increased evapotranspiration, more water for agriculture
6	Low temperatures, frosts, cold waves (Mainly in high altitude areas)	• Crop losses

Of the above risks, the first three (flood, landslides and changes in seasonal water availability) will impact irrigated agriculture production directly, while the impact of the other will be more indirect.

6.4 Present coping strategies and likely future needs for irrigation

Irrigation in Bhutan mainly refers to community managed irrigation systems (CMIS) that were built by farmers with local means and traditional methods over many years. These systems were so developed

[33] It is estimated that with every 1° C rise in temperature, agricultural water demand would increase by 6 to 10% or more (IPCC, 2007a) – cited by Annex C 3.6, water adaptation to climate change in Bhutan, an update

that they have been providing a coping strategy to climate variability and extreme weather. The concepts of “design to fail”, “over sizing of canal” and “higher flexibility in management” are some of the responses adopted to cope up with these variability.

The concept of “design to fail” is seen suitable to cope up with unexpected severe floods. An example is very simple looking infrastructures in river that are built using local knowledge and skills, which get washed away after every major flood, but that can be re-built relatively easily after the floods. This concept of “design to fail” not only reduces the costs of infrastructure but also ensures that the effects of failure are controlled.

Likewise, over sizing of canal of existing irrigation systems is another strategy adopted by most community managed irrigation systems to cope up with variability[34] in water supply. Many times, due to fluctuating water availability in river, either there is not enough water or water available is abundant. Due to this uncertainty, farmers tend to divert more water when available and store them in the terraces or root zones for later use. For this reason, existing canals tend to have larger section to allow transportation of additional water when available.

Higher flexibility in water management in response to varying levels of supply is the most common strategy being adopted by many community managed irrigation systems worldwide, including in Bhutan.

Though these strategies have worked well in the past, they may no longer be sufficient to cope with the projected climate change impacts. Thus, several alternatives may need to be examined to address the risks. Some such alternatives are:

For risks due to flooding and flash floods

- Adopt infrastructural measures for flood protection like safety embankment, bypass channel etc
- Re-visit design standard for greater resilience
- Maintain concept of design to fail with modification

For risks due to change in seasonal availability of water (flow reduction or fluctuating flows)

- Adopt appropriate management options to increase irrigation efficiency
- Reduce irrigated areas
- Initiate cultivation of low water demanding crops
- Introduce intermediate water storage to cope with the decreasing and fluctuating water supply
- Increase free board in the canal to allow transportation of extra water when available for storing in the root zone or terraces for later uses.
- Initiate deficit irrigation, a concept of managing irrigation under water scarce situation.

For risks due to landslides

- Adopt infrastructural measures that focus to flexible infrastructure
- Promote bioengineering means of slope stabilization
- Maintain concept of “design to fail” with modifications

6.5 Impact of climate change on agricultural production

Impacts of climate change on agricultural production vary according to whether the crop production system depends on the irrigation or summer monsoon. In the case of irrigated agriculture, likely impacts due to climate change further depends on the type of water sources: snow-fed source, storage system,

[34] Studies of irrigation database prepared by DOA suggest that most of the community managed irrigation systems have much larger canal capacities compared to their requirements. Though there could be some other reasons for this, one of the reasons of having larger canal capacity is to cope up with the fluctuating flows in the river.

or run-of-the river system etc. In systems that depend on the summer monsoon, multiple scenarios are possible.

In Bhutan, about 215,000 acres of land are cultivated under rain-fed conditions that depend on monsoon rains, while about 64,000 acres are irrigated. Even in the case of irrigated agriculture, as most irrigation systems are of run-of-the river type drawing water from the second or third order tributary rivers whose flows depend almost on monsoon rains, impact of climate change on agricultural production under irrigated agriculture will also be high.

Further, as most of the farmland in Bhutan is located on hill slopes, it is likely to face increasing risks of landsides due to projected higher intensity and more erratic rainfalls. This phenomenon will further impact agricultural production.

However, it is difficult to quantify the magnitude of the climate change impacts on agricultural production, and studies on this topic are still limited. Following are some of the research findings conducted in Nepal[35] and Bhutan.

1. The future impacts of climate change on agricultural production as calculated by Cline (2007) suggest an initial increase of production until 2050, caused by carbon fertilization, followed by a decrease of 4.8% by 2080, based on the assumption of a positive carbon fertilization effect from a temperature increase of up to 2.5°C.

2. An analysis conducted by the Nepal Agricultural Research Council (NARC) using simulation models for major crops such as rice, wheat and maize suggested that under elevated CO2 and a 4 °C temperature increase rice yields might increase by 3.4% in the subtropical lowland areas, 17.9% in the hills and 36.1% in the mountains. Wheat production might increase by 41.5% in the low land areas, 24.4% in the hills and 21.2% in the mountains under elevated CO2, but would be significantly decreased by a 4°C temperature rise (Selvaraju, R, 2014).

   The two projections (Cline and NARC) mentioned above, however, are based on ideal potential production conditions mainly conditioned by CO2 and temperature. These figures do not reflect the most likely negative impacts on agricultural production due to extreme climatic events which are likely to increase in frequency and intensity during this time span.

3. A recent research conducted in the West Seti river sub-basin of Nepal (mountainous environment) suggests that with the actual change in ET by-1.9% in rice, -1.1% in maize, -2.0% in millet, +6.7% in wheat and +5.4% in barley under future climate projections, yield of maize and millet will decrease by 5.9% and 8.0% whereas yield of rice, wheat and barley will increase by 1.2%, 6.6% and 7.0% respectively (Gurung, P., Bharati, L. and Karki, S. 2015). The study used the Soil and Water Assessment Tool (SWAT) to simulate water balances in different cropping patterns under current and future climatic scenarios.

4. With regard to Bhutan, considering that rice is the preferred staple food, Ahmed, M. and S. Suphachalasai (2014) categorized the paddy producing areas in three categories: low altitude zone (38% area coverage), mid-altitude zone (50% area coverage), and high altitude zone (12% area coverage). Accordingly, based on the current and expected maturity days for cultivating paddy, expected paddy yields are forecasted for 2030 and 2060 as below (Figure 6.3)

[35] As the agro ecological features of Nepal match well with that of Bhutan, research findings in Nepal well be relevant to Bhutan as well.

Figure 6.3: Changes in paddy yields in different regions due to change in crop maturity days

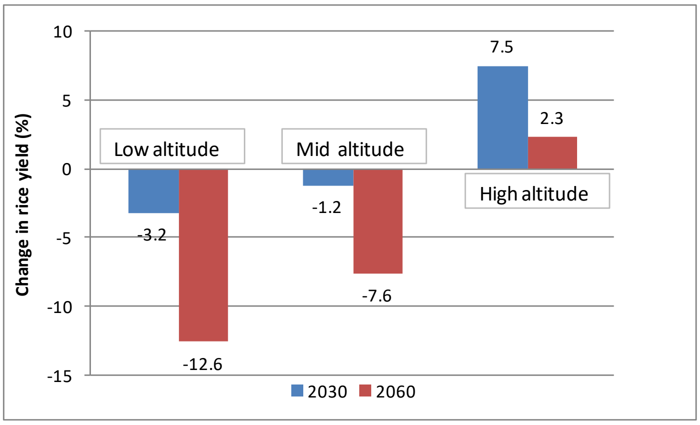


Figure 6.3 indicates that the expected yield of paddy is likely to be reduced in the low and mid altitude zones, while its yield in high altitude zone is likely to be increased.

5. Referring to the 2007 IPCC AR4, Ahmed, M. and S. Suphachalasai (2014) further noted that production of cereal crops in the South Asian countries could decline by 4%–10% by 2100.

6. In the longer term, the total economic costs associated with climate change impacts are likely to increase in Bhutan. If no action is taken to adapt to and mitigate global climate change, the average total economic losses are projected to be 6.6% for Bhutan (Ahmed, M. and S. Suphachalasai 2014)

In sum, above research findings suggest that although there may be some gains in agricultural productions in some regions of Bhutan, the overall impacts of climate change on agricultural production are likely to be negative. Further studies are needed to better understand this relationship.

6.6 Potential responses to climate change in planning irrigation development

Climate change offers an opportunity as well as a threat to Bhutan. Thus, it is essential that impacts of climate changes are defined, mitigation measures identified, and implemented in a systematic and planned approach while developing irrigation in the country.

Bhutan experiences greatest variety of climate due to its wide altitudinal variations across short distances. As a result, impact of climate change on irrigation development varies from place to place. Further, to what extent climate change induced impacts are sensitive for any irrigation development project / subproject is also shaped by nature and by the type of project. For example, an irrigation system that acquires water from a reliable water source (small reservoir, lift from a perennial large river etc) is more resilient to climate change compared to a run of the river irrigation system that acquires water from a seasonal stream.

Therefore, the response to climate change should be adapted to the local context of natural resource endowments, livelihood activities, vulnerability patterns and adaptive capacity. Efforts to respond to climate change should build on local perceptions of climate risks and existing coping strategies. This calls for a comprehensive approach for addressing climate change induced problems through the short, medium and long term approaches.

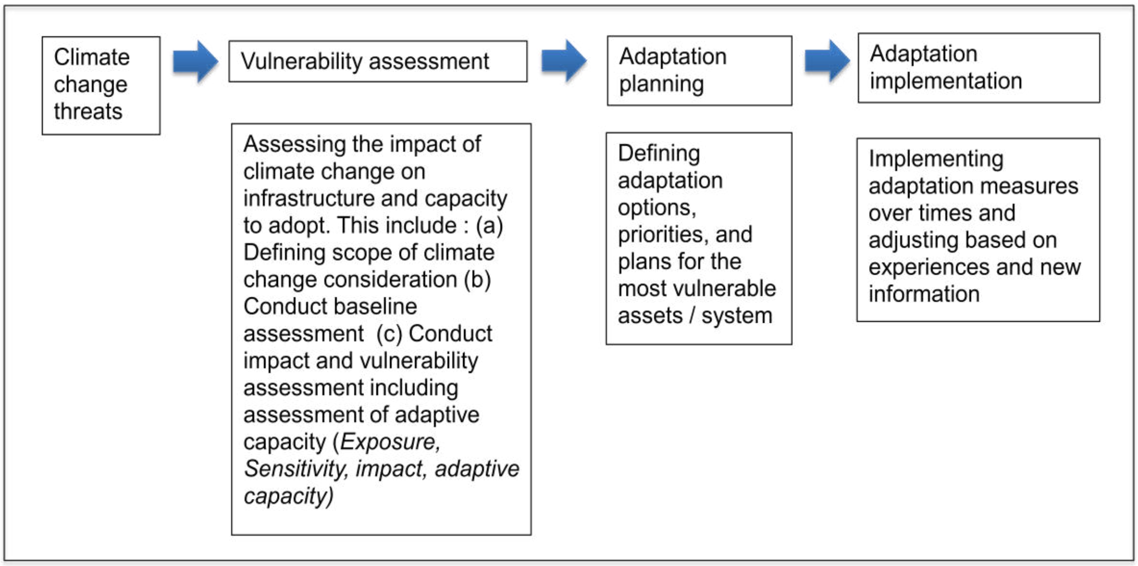
Thus, for each irrigation infrastructure project, climate change impacts and the measures to mitigate them are to be recognized in a process of infrastructure planning, design and implementation. This process is also referred to as "mainstreaming" climate change.

The main objectives for mainstreaming climate change in irrigation planning are:

- To set priorities for adaptation and resilience of the most vulnerable irrigation infrastructure.
- To develop planning systems that accommodates climate change as part of the normal planning process in designing and implementing irrigation system.
- To guide adjustment in irrigation infrastructure as climate changes and adaptation performance is monitored.

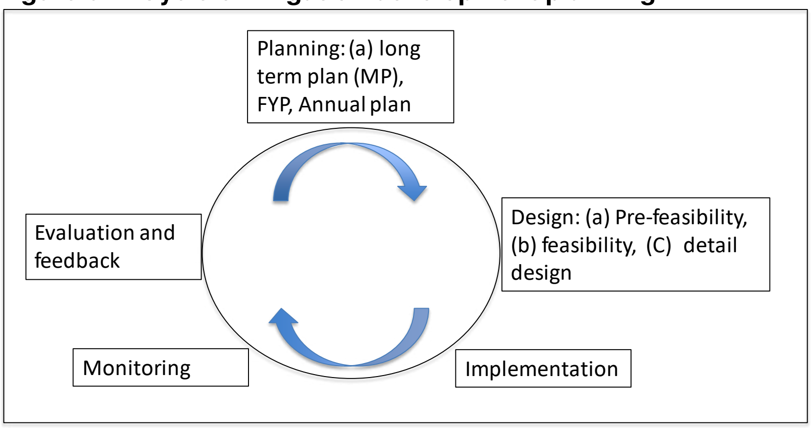
6.6.1 Mainstreaming climate change in planning irrigation development

ICEM (2013) suggested following approach for mainstreaming climate change in infrastructure planning process that includes irrigation:



In the cycle of irrigation development planning, irrigation infrastructures are studied and evaluated at four different stages. The broad planning process is the first stage, while the other three stages correspond to the pre-feasibility, feasibility, and detail design stage (Figure 6.4).

Figure 6.4: Cycle of irrigation development planning



Climate change is best considered at the levels of planning, pre-feasibility and feasibility studies[36]of the project planning cycle. At the level of planning, the system as a whole (or a complete irrigation system)

36 At the level of detailed design, the focus of an infrastructure project narrows toward specific details, and thus the ability to make major adjustments in response to climate change impacts and threats is reduced

is examined from the perspective of climate change, and the irrigation systems will be prioritized for further study based on their resilience to climate change.

6.7 Summary and recommendations

It is understood that the overall impact of climate change on the Bhutan's irrigation systems and subsequently in overall agricultural production is likely to be negative. Following are some of the prominent influence areas:

- Almost all the existing irrigation systems in Bhutan have been developed by communities since long using local skill and materials, and their present infrastructural state to stand against climate change is quite poor. The infrastructures are likely to be deteriorated more rapidly as a result of expected more frequent and severe floods and landslides due to climate change. This will affect agricultural production negatively.
- About three forth of the agricultural land in Bhutan is rain-fed that depends almost entirely on the monsoon rain for crop production. Hence, impact of climate change on Bhutan's overall agricultural production is high.
- Most irrigation systems in Bhutan are of run-of-the river type that draws water from the second or third order tributaries of large rivers. Flows in such tributaries depend almost exclusively on monsoon rains. This means, existing irrigation systems in Bhutan are not climate resilient. As a result, climate change will negatively impact rainfed as well as irrigated agriculture production.
- Analysis of past data suggests that the present level of agricultural production in Bhutan is not increasing. This situation is likely to further deteriorate in the future as a result of climate change. Though, it is difficult to quantify how climate change will impact on Bhutan's agriculture in the long term, it is predicted that crop production may reduce by 4% to 10%, if appropriate measures are not taken to mitigate the effects of climate change.

It is thus proposed to adopt appropriate measures to mitigate the likely impact of climate change on agricultural production. One such measure is to develop irrigation facilities through the development of irrigation systems. However, such irrigation should be less vulnerable to climate change and these should be climate resilient.

In order to develop climate resilient irrigation systems, there is a need to mainstream climate change component in the irrigation planning process. For this, it is proposed to include climate change vulnerability assessment at the level of pre-feasibility and feasibility level of irrigation studies, and accordingly projects should be prioritized based on their resilience to climate change. Multi Criteria analysis described in forthcoming Chapter presents some of the criterions for identifying climate resilient projects.

7. Irrigation planning

7.1 Irrigation zoning and crop planning

7.1.1 Irrigation zoning

Irrigation zoning helps crop planning for irrigated agriculture. This is specifically true in the case of Bhutan with varied relief and considerable altitudinal variations leading to diversified agro-ecological settings. Following these agro-ecological settings, Bhutan is divided into five irrigation zones whose details are presented in Table 7.1 below.

Table 7.1: Irrigation zones and their main characteristics

SN	Irrigation zone	Altitude range (m)	Cultivated area (%)	Main characteristics	Focus area
1	Cool temperate high mountain zone	2600-3600	8	Less cultivated area, low rainfall, low temperature, cold water	Bumthang, Haa
2	Warm temperate high altitude zone	1800-2600	20	Low rainfall, warm temperature during summer, cold water, small river valleys	Thimpu, Paro
3	Dry sub-tropical medium altitude zone	1200-1800	33	Lower rainfall, dry winter and warm summer, broad river valleys	Punakha, Wangdue
4	Humid sub-tropical mid-altitude zone	600-1200	22	High rainfall, warm temperature, steep slope terraces, dense vegetation	Tsirang, Dagana, Trashigang
5	Wet sub-tropical low altitude zone	100-600	17	High and intense rainfall, rolling slope and plain area, hot summer	Smatse, Sarpang and SamdrupJonkhar

The cool temperate high mountain zone is not considered potential for irrigated agriculture, though people have started cultivating irrigated paddy in Bumthang valley (2,800 m) since 2004[37]. Others zones show great potential for irrigated agriculture.

Except for the wet sub-tropical low altitude zone that consists of relatively large plains and gentle slopes, other four zones comprise river valleys and hill slopes, which have been beautifully terraced for water control. These terraces are being intensively utilized for irrigation with numerous traditional irrigation systems built across hill slopes that receive water from the nearby water sources either through a temporary or permanent diversion structures. The paragraphs below describe crop planning for each of the above zone.

7.1.2 Crop planning

Crop planning for the NIMP is shaped by the food and nutritional security policy of Bhutan that calls for a more diversified crop production system. It entails production of cereals as staple food along with production of high value crops and livestock feeds. Besides this, features of the irrigation zones,

37 Personal communication with DOA officers

prevailing trends of crop production and their contribution to GDP, and on-going crop development programs also influence crop planning for NIMP.

Furthermore, the type of irrigation technology used also determines the crops that can be grown. For example, though paddy is the preferred crop for irrigated Chhuzhing under surface irrigation, it cannot be grown in Kamzhing under hill slope irrigation using technologies such as sprinklers for instance.

Below are some of the main crops that are planned under the NIMP.

Paddy: Rice (paddy) is the most important staple crop in Bhutan and its production is synonymous to food security. As a result, all the preceding FYP set targets for the production for paddy (rice). So, its significance for NIMP is self-explanatory. The NIMP proposes to further develop cultivation of paddy under the conventional flood (surface) irrigation systems.

Maize: Maize is second most important cereal crop in Bhutan cultivated both for human consumption and animal feeds. Traditionally it is cultivated in upland (Kamzhing) under rain fed condition, which is termed here as "**summer maize**". Maize cropped areas and annual production are currently declining. Though maize is traditionally cultivated under rain-fed condition, present climatic conditions demand irrigation during the early stage of crop development. This will increase crop yield and provide insurance against crop failure due to long dry spell. The NIMP thus proposes to introduce irrigation to summer maize by developing irrigation facilities to irrigate Kamzhing and other suitable cultivated land.

Maize can also be cultivated in irrigated terraces (Chhuzhing) during the spring season (Feb-June), which is termed here as "**spring maize**". However, unlike summer maize, spring maize needs to be cultivated within a specified time slot as delay in its cultivation would hamper cultivation of successive crop of paddy, which is the main crop. Because of the limited flexibility in sowing time for spring maize, it will not be possible to wait for the rain, and thus pre-sowing irrigation is essential without which the crop may not germinate. As most of irrigated terraces presently remain fallow after the cultivation of paddy (paddy - fallow system), cultivation of spring maize in irrigated terrace would help increasing cropping intensity. In Bhutan, cultivation of spring maize has already been initiated, and it is broadly accepted by farmers (Wangchuk, D and Katwal, T.B. 2014).

Maize is also one of the most important livestock feeds[38] . As production and consumption of livestock products (meat, milk, egg etc) are increasing rapidly in Bhutan, there is likely to be a shortage of animal feeds (mainly maize)[39] in the future.

Recognizing its benefits, the NIMP propose to intensify cultivation of irrigated spring maize on terraces currently under the paddy-fallow system.

Wheat: although the cropped area has gradually declined from 21,900 acres in 2005 to 5,560 acres in 2010 (it tends to be stable since 2010), wheat remains a major cereal crop in Bhutan. As in other Asian countries, it is expected that the wheat products will become more important and partially substitute for rice in the Bhutanese diet. Considering this aspect, the NIMP proposes to intensify wheat cultivation in Bhutan.

Potato: Potato is one of the most important cash crops in Bhutan. Presently, it is cropped on about 1,391 acres, and the annual production is about 50,390 Mt (3,763 kg/acre) (DOA AS, 2013).

38 Maize cropped in wetland also contributes to green fodder. In fodder led farming system, maize is sown with a much higher seed rate to maintain a high plant density in the wetland. During May-June when fodder becomes scarce, the tender maize is harvested and fed to the productive animals. The farming of fodder maize is gaining popularity in peri–urban areas of Thimphu and Paro Dzongkhags

39 Discussion with the professionals of the Karma feed, a leading livestock feed producer of Bhutan, suggests that maize (55%), soya meal (25%), and rice bran (20%) are the key ingredients of livestock feeds. About 30% of these are consumed by the dairy production sector, while 60 and 10% are consumed by poultry and pigs respectively. Presently, all the ingredients (about 17,000 Mt) that are used in producing livestock feeds are imported from India.

Potatoes are usually grown in dry land under rain fed conditions[40], termed here as summer potato. But in some cases, especially in low land areas (below 1500 msl), potatoes are also cropped in wetland (Joshi and Gurung, 2009). In the context of changing climatic conditions, summer potatoes require irrigation especially during the early stage of cultivation. Irrigation will increase crop yield and provide insurance against crop failure in case of long dry spells.

Potatoes can be cultivated in a wide variety of environments. In Bhutan, as most of the irrigated fields after the cultivation of paddy harvest remain fallow, cultivation of winter potato (in Chhuzhing) under irrigated condition would increase cropping intensity and provide additional income to the farmers.

Experiments conducted in the Nepalese mountains suggest that potato can be profitably cropped as a cash crop after paddy (November to February) in irrigated terraces between 800 and 1500 meters[41]. Potato as a winter crop on irrigated terraces has also been introduced in southern Bhutan by the Ministry of Agriculture. The interim result suggests that winter potato can be harvested in February with good yield[42].

Further, though Bhutan exports potatoes from June to December, it imports potatoes during the late winter and spring season. The NIMP thus aims to introduce and intensify cultivation of irrigated winter potatoes to reduce imports at that time.

Cash crops: Cash crops grown in Bhutan include pulses, mustard, legume, cardamom, ginger, and chilli. Many of these crops are non-perishable, and can be grown in different agro ecological conditions. These cash crops are becoming more popular among the farming communities of Bhutan, and their cultivation is growing rapidly (Figure 1.20). Besides this, Bhutan can also produce a wide variety of off-season vegetables like potato, cabbage, carrot, green chilli etc due to its wide agro-ecological diversity. Provided that the roads and means of transportation are good enough, such vegetables can be easily marketed in the neighbouring countries.

Considering these opportunities, the NIMP proposes to intensify the cultivation of the above mentioned cash crops along with off-season vegetables.

Orchards: Mandarin orange and areca nut are the main orchards grown in Bhutan, which is followed by apple. Presently, many of these orchards are cultivated under rainfed conditions. However, awareness is being raised on the importance of irrigating these crops for higher yield and better quality fruits[43]. This is especially true in the context of likely draught and long dry spell as a result of climate change. The NIMP thus proposes to intensify cultivation of orchards under irrigation.

7.1.3 Cropping patterns

Eight different cropping patterns are proposed for the NIMP from the above selected representative crops. These are listed below. Their cultivation timelines, which vary greatly across irrigation zones, are evaluated based on local context. However, variations across east-west regions are not taken into account for designing cropping patterns, as these variations are not determinant.

1	Spring maize –paddy	5	Paddy – fallow
2	Paddy –vegetable, chilli	6	Paddy – wheat

40 Refer: http://foodsecurityatlas.org/btn/country/availability/agricultural-production

41 Refer: http://www.fao.org/docrep/003/X6906E/x6906e09.htm and http://www.narc.gov.np/org/potato_research_program.php

42 Refer: http://www.moaf.gov.bt/off-season-production-of-potatoes-the-norbugang-experience/

43 Recommended irrigation for areca nut is: once in a week during November to February and once in 4 days during March to May. It is to be noted that these are seasons with no rain fall. Expected yield of areca nut is 1250 kg per ha, which is higher than the present yield in Bhutan (source: http://agritech.tnau.ac.in/horticulture/horti_plantation%20crops_arecanut.html)

3 Paddy –winter potato
4 Orchard
7 Paddy – oilseed, legumes, pulses
8 Paddy – paddy

Proposed cropping patterns and areas of coverage are designed with a view to achieve an average cropping intensity of over 150%. The highest cropping intensity is proposed for the wet sub-tropical low altitude zone where paddy and spring maize cover significant areas, whereas the cropping intensity for the cool temperate high mountain zone would be lowest. The following sections present the crop planning details for each irrigation zone.

7.1.3.1 Cool temperate high mountain zone

Crop planning for the cool temperate high mountain zone (2,600 to 3,600 m) is based on a mono cropping sequence. The representative crops of this zone are potato, maize, wheat and buckwheat, most of which are presently cropped under rain fed condition. In the proposed crop planning, it is assumed that yields of crops like potato and wheat will be increased with the introduction of irrigation. The proposed cropping intensity of this zone is only about 50%. Table 7.2 presents the proposed cropping patterns under irrigated condition with planting and harvesting dates

Table 7.2: Proposed cropping patterns for the cool temperate high mountain zone

Crops	Proposed area coverage (%)	Date of transplant	Harvesting date
Potato- fallow	15	March	August
Maize – fallow	05	March	October
Wheat – fallow	15	November	June
Buckwheat – fallow	15	September	June

7.1.3.2 Warm temperate high altitude zone

Crop planning for the warm temperate high altitude zone (1,800 to 2,600 m) is partly based on double cropping sequence and partly on single cropping. The representative crops of this zone are paddy, wheat, maize, oil seeds (mustard), pulses and legumes. Presently, farmers grow paddy in Chhuzhing, which then remain fallow during the rest of the season, whereas other crops are cultivated in Kamzhing under rainfed conditions. Table 7.3 presents the proposed irrigated cropping patterns with planting and harvesting dates.

Table 7.3: Cropping patterns for the warm temperature high altitude zone

Crops	Proposed area coverage (%)	Date of seed bed	Date of transplant	Harvesting date
Paddy – fallow	40	April/May	May /June	October
Paddy – Legume, oilseed, pulses	15	April	May	October
			December	April
Summer potato - off season vegetable	15		March	Aug / September
			December	March / April
Paddy – wheat	15	May	June	November
			December	May
Orchard (Apple, apricot etc)	15	Round the year		

Table 7.3 suggests that about 40% of the irrigated area will remain fallow after October. Total coverage of paddy is about 70% of the irrigated area. The proposed cropping intensity is about 145%.

7.1.3.3 Dry sub-tropical medium altitude zone

The representative crops of the dry sub-tropical medium altitude zone (1,200 to 1,800 m) are paddy, potatoes, vegetables, pulses, legumes, and orchards. Table 7.4 presents proposed cropping patterns with planting and harvesting dates.

Table 7.4: Cropping patterns for the dry sub-tropical medium altitude zone

Crops	Proposed area coverage (%)	Date of seed bed	Date of transplant	Harvesting date
Paddy – fallow	40	May	June	October
Paddy – vegetable, Chilli, pulses, legumes	20	Feb-March	March / April	August
			September	March
Paddy – wheat	15	May	June	October
			December	April / May
Paddy- winter potato	15	May	May / June	September
			November	March
Orchard: Mandarin, peach, apple	10		Round the year	

All crops in the above mentioned cropping patterns are proposed to be irrigated in order to increase crop yields. As in the case of the warm temperate high altitude zone, paddy covers 90% of the irrigated area in wet season, while 10% of the area is planned to be covered by orchards. Likewise, winter potatoes, vegetables, and chilli cover almost half of the irrigated area in the dry season. Average planned cropping intensity is about 150%.

7.1.3.4 Humid sub-tropical mid-altitude zone

The humid sub-tropical mid altitude zone lies between 600 and 1200 m, and its main crops are paddy, wheat, maize, vegetables, and orchards. Proposed cropping patterns for irrigation in this zone are presented in Table 7.5

Table 7.5: Cropping patterns for the humid sub-tropical mid altitude zone

Crops	Proposed area coverage (%)	Date of seed bed	Date of transplant	Harvesting date
Paddy – fallow	20	May	June	October
Paddy – wheat	10	May	June	October
			December	May
Paddy- winter potato	15	May	June	October
			November	March
Spring maize – paddy	25		February	June
		June	July	October
Paddy – vegetable, Chilli, pulses, legumes	20	June	July	October
			January	April
Orchard: Mandarin, Guava	10		Round the year	

As in other zones, 90% of the irrigated area is proposed to be cropped with paddy. The spring maize is proposed on 25% of the area. In addition, vegetables, oilseeds, pulses and chilli shall cover about 20% of the area. 10% is proposed for orchards. The proposed cropping intensity is about 170%.

7.1.3.5 Wet sub-tropical low altitude zone

Crop planning for the wet sub-tropical low altitude zone (150 to 600 m) is based on double cropping with two crops of paddy in some areas. The representative crops of this zone are paddy, maize, wheat, mustard, vegetables, and orchards. Table 7.6 presents the proposed cropping patterns.

Table 7.6 : Cropping patterns for the wet sub-tropical low altitude zone

Crops	Proposed area coverage (%)	Date of seed bed	Date of transplant	Harvesting date
Paddy – fallow	10	June	July	November
Paddy – Paddy	10	June	July	November
		January	February	June

Paddy- Wheat	10	June	July	November
			Nov / December	April
Spring maize-Paddy	25		February	June
		June	July	November
Paddy – winter potato	15	June	July	November
			December	April
Paddy – vegetable, Chilli, pulses, legumes	20	June	July	October
			Nov / December	Feb / March
Orchard: Acera nut, mango, Litchi	10		Round the year	

As in the other irrigation zones, 90% of the irrigated area in the wet season is proposed to be cropped with paddy. Proposed area coverage for other crops is 30% for spring maize, 10% each for pulses / legumes / oilseed and vegetables, 10% for spring paddy, 10% for wheat and 10% for orchards. With this, total cropping intensity will be about 180%.

7.1.3.6 Proposed cropping patterns for irrigating Kamzhing under dry land irrigation

Besides developing conventional irrigation on Chhuzhing, the NIMP also aims to introduce dry land irrigation for Kamzhing. Though some of the fields will be terraced, others will remain on slopes and will be irrigated through appropriate technologies. As the proposed cropped areas under dry land irrigation will be located in the upper watersheds that are significantly vulnerable to climate change, the dry land irrigation development program will cover all the irrigation zones except the cool temperature high mountain and wet subtropical low altitude zones. Orchards, off-season vegetables, legumes / pulses, spring maize, and paddy are some of the main crops proposed for irrigation. Below is the proposed cropping patterns and area of coverage in percentage:

Crops	Area coverage (%)
Paddy– Off season vegetable / Chilli	20
Summer maize – pulses, legumes, oilseed	10
Off season vegetables (summer) – pulses, legumes, oilseeds,	10
Orchards	60

7.1.3.7 National average cropping intensity

The national average cropping intensity is estimated from the weighted average cropping intensity for each irrigation zone. While doing so, cool temperate high mountain zone is excluded as crops in this zone are mostly grown under rain-fed condition. Table 7.7 presents the percentage cropped area coverage as per the total cultivated land in the country, respective cropping intensity per irrigation zone and the weighted cropping intensity that totals to 159%.

Table 7.7 : Weighted cropping intensity (CI) per irrigation zone and national average

SN	Irrigation zone	Approximate area coverage (%)	Proposed cropping intensity	Weighted cropping intensity
1	Warm temperate high altitude zone	22	145	32
2	Dry subtropical medium altitude zone	35	150	53
3	Humid subtropical mid-altitude zone	24	170	41
4	Wet subtropical low altitude zone	18	180	33
	Total	100		159

7.2 Water requirement assessment

The assessment of the water requirement for the computation of water balance has been carried out with the selection of representative climatic stations, analysis of the long-term climatic data and calculation of potential evapo-transpiration using FAO developed software Cropwat-8. In addition, selection of representative crops and cropping patterns, calculation of monthly 80% reliable rainfall and effective rainfall, assessment of water use efficiencies and irrigation application losses have also been carried out to assess the monthly water demand. Results are summarized hereunder.

7.2.1 Representative climatic stations

All the Class-A climatic stations in Bhutan are considered to be representative stations for the assessment of the water requirement. The main criteria applied for the selection of the stations are geographic location, availability of reliable climatic data, and adequate rainfall data. Twenty Class-A climatic stations which have relatively long-term data were selected for the calculation of crop water requirement (Table 7.8)

Table 7.8: Representative Class A climatological stations

S.N	Stations	Location	Altitude (m)	Data range
1	Bhur	Sarpang	390	1996-2014
2	Chamkhar	Bumthang	2,470	1996 - 2014
3	Dagana	Dagana	1,460	1996 - 2014
4	Damphu	Tsirang	1,520	1990 - 2014
5	Deothang	SamdrupJonkhar	890	1993 - 2014
6	Gasakhatey	Gasa	2,760	2003 - 2014
7	Kangma	Trashigang	2,005	1994 - 2014
8	Trangmachhu	Lhuntse	1,750	2006 - 2014
9	Mongar	Mongar	1,580	1996 - 2014
10	Namjeyling	Haa	2,751	1996 - 2014
11	Paro DSC	Paro	2,406	1995 - 2014
12	Pemagatshel	Pemagatshel	1,780	1992 - 2014
13	Phuntsholing	Chhukha	270	1996 - 2014
14	Punakha	Punakha	1,236	1990 - 2014
15	Simtokha	Thimpu	2,310	1995 - 2014
16	Sipsu	Samtse	413	1995 - 2014
17	TrashiYangtse	TrashiYangtse	1,810	1990 - 2014
18	Trongsa	Trongsa	2,120	1996 – 2014
19	Wangdue RNRRC	Wangdue	1,180	1990 – 2014
20	Zhemgang	Zhemgang	1,820	1990 – 2014

Source: DHMS (Department of Hydrological and Meteorological Services)

Some of the selected stations do not have enough climatic data. However, in order to cover the whole country, all Class-A stations have been considered for agro-ecological as well as irrigation zoning. The geographical coverage of these stations is presented in Figure 7.3. With respect to the irrigation zones, Namjeyling, Gasa and Chamkhar represent the cool temperate high mountain zone; Paro DSC, Simtokha, Kangma and Trongsa represent the warm temperate high altitude zone; Dagana, Damphu, Mongar, Pemagatshel, Punakha, TrashiYangtse, Lhuntse and Zhemgang represent the dry sub-tropical medium altitude zone; Deothang and Wangdue RNRRC represent the humid sub-tropical mid-altitude zone; and Bhur, Phuntsholing and Sipsu represent the wet sub-tropical low altitude zone.

7.2.2 Monthly climatic data

Climatic data for the calculation of irrigation water requirement have been gathered and compiled from the above mentioned climatic stations. The collected data have been examined for their consistency, and long-term monthly data have been computed using various tools and techniques. A summary of mean monthly data is presented hereunder (Table 7.9)

Table 7.9: Summary of climatic data

Station	Altitude (m)	Temperature (^{0}/C) Max	Min	Rainfall (mm)	Relative humidity (%)	Wind speed (m/s)	Sunshine duration (hr)
Bhur	390	27.13	19.71	5,098	77.18	0.65	4.95
Chamkhar	2,470	17.67	5.86	760	72.33	1.37	5.18
Dagana	1,460	18.63	13.01	1,853	79.92	0.98	5.13
Damphu	1,520	21.06	12.89	1,498	79.00	1.47	6.07
Deothang	890	25.31	16.69	3,724	76.89	1.09	5.35
Gaga	2,760	16.00	6.56	1,557	77.12	0.85	5.13
Kangma	2,005	21.11	10.65	1,171	75.30	1.02	3.42
Lhuntse	1,750	24.80	14.72	851	79.94	1.13	4.53
Mongar	1,580	23.13	12.77	907	77.03	0.47	4.96
Namjeyling	2,751	16.31	4.89	866	72.84	0.85	5.45
Paro DSC	2,406	19.88	8.22	661	70.18	0.59	4.83
Pemagatshel	1,780	21.58	12.05	1,848	76.52	0.45	4.87
Phuentsholing	270	29.77	19.84	3,888	79.08	0.87	4.83
Simtokha	2,310	22.04	8.24	597	67.78	0.97	5.68
Sipsu	413	26.43	19.93	5,457	69.27	0.97	4.58
TrashiYangtse	1,810	20.21	10.94	1,172	77.85	1.02	4.65
Trongsa	2,120	20.87	11.11	1,220	80.96	0.54	4.56
Wangdue RNRRC	1,180	25.00	13.96	675	72.68	1.31	5.51
Zhemgang	1,820	18.63	11.97	1,349	81.17	0.61	4.86

Source: DHMS

7.2.3 Calculation of reference crop potential evapo-transpiration

Potential evapo-transpiration is assessed from the calculation of the reference crop evapo-transpiration (ETo) which represents the rate of evapo-transpiration of green grass under ideal conditions, 8 to 15 cm tall, with extensive vegetative cover completely shading the ground.

Cropwat-8 is a FAO developed computer software model being extensively used to calculate crop water requirements and irrigation requirements with climatic and crop data. For this NIMP, Cropwat-8 has only been used for the calculation of reference crop evapo-transpiration (ETo) and effective rainfall. The input data for Cropwat-8 are long term minimum and maximum temperature, mean relative humidity, wind speed, and sunshine duration. For all 20 representative climatic stations ETo have been computed in the model (mm per day), and the summary of the monthly ETo is presented in Table 7.10

Table 7.10: Reference crop evapo-transpiration (ET0) of representative stations (mm)

Station\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bhur	62.3	67.8	95.5	98.1	107.6	89.4	90.5	96.1	91.2	95.8	75.6	63.2	1033.1
Chamkhar	50.5	56.6	78.4	87.6	101.1	98.4	98.6	99.5	89.1	80.3	60.6	49.9	950.6
Dagana	48.7	54.6	78.7	86.4	88.0	93.0	96.1	93.3	93.9	80.3	56.7	49.0	918.7
Damphu	56.1	63.3	92.7	103.5	110.4	98.7	96.7	100.4	92.7	92.7	69.0	57.4	1033.5
Deothang	67.3	73.4	102.0	101.7	105.7	91.5	94.6	96.4	90.9	95.5	79.8	70.7	1069.4
Gasa	44.3	48.4	69.1	87.0	102.0	95.1	97.7	97.3	85.8	75.0	49.5	40.9	892.2
Kangma	70.4	67.8	83.1	82.5	87.1	88.8	97.0	100.4	97.8	88.0	75.9	71.3	1010.1
Lhuntse	54.9	60.8	80.3	93.6	108.2	113.7	139.5	100.8	89.7	81.5	60.0	49.9	1032.8
Mongar	48.1	58.5	81.5	88.8	102.3	93.9	95.2	98.9	92.1	82.8	59.1	49.0	950.1
Namjeyling	47.1	52.6	75.0	87.0	98.6	91.8	97.7	96.1	83.4	75.3	57.0	47.4	909.1
Paro DSC	45.3	54.9	78.4	90.6	103.5	96.0	97.3	97.3	84.9	78.7	55.2	42.5	924.7
Pemagatshel	49.9	56.8	78.4	88.8	98.6	86.7	86.5	92.4	87.9	84.3	60.3	50.5	921.2
Phuentsholing	59.2	72.0	103.5	112.8	119.0	101.4	99.5	102.9	92.4	100.1	80.7	66.0	1109.6
Punakha	50.2	58.2	86.2	104.7	121.5	114.3	115.0	114.4	99.0	87.4	60.0	48.1	1059.0
Simtokha	53.0	62.2	89.6	102.9	115.0	108.0	113.8	110.4	96.9	88.0	65.4	53.9	1059.1
Sipsu	66.0	72.5	109.7	115.2	116.9	96.9	92.7	95.2	89.7	100.1	79.8	66.3	1101.1
Trashi Yangtse	48.4	54.9	74.1	83.4	96.7	93.3	99.2	97.7	88.2	80.9	58.2	47.1	922.0
Trongsa	45.6	54.6	76.9	87.6	94.2	88.2	90.5	93.6	87.0	79.4	57.3	46.5	901.4
Wangdue	56.1	65.5	97.7	114.0	128.7	119.1	118.1	115.9	100.5	95.2	65.4	53.3	1129.5
Zhemgang	46.2	50.4	72.5	83.1	94.6	89.4	90.8	93.0	84.3	80.0	57.9	47.1	889.3

7.2.4 Assessment of 80 percent reliable rainfall

Rainfall contributes to satisfying crop water requirement in a greater or lesser extent depending upon the location. How much water is coming from rainfall and how much water should be covered from irrigation is unfortunately difficult to predict as rainfall varies from season to season, year to year. In addition, not all the rain that falls in the ground is used by the plant: some rain is lost through percolation and some by evaporation. The amount of rainfall that can be effectively used for plant growth is referred to as “effective rainfall”.

The amount of rainfall which can be depended upon in 1 out of 5 years corresponding to the 80% probability of occurrence is referred to as “80% reliable rainfall”. FAO recommends using 80% reliable rainfall for irrigation system design, which is assessed from time series meteorological data using various methods. The 80% reliable rainfall has been computed from processed long-term monthly data using probabilistic method. The effective rainfall has been calculated from the 80% reliable rainfall using Cropwat-8. The results are presented in Table 7.11 and Table 7.12.

7.2.5 Analysis of reliable rainfall and evapo-transpiration (ETo)

The results of the reference crop evapo-transpiration (ETo) computation show that its variation across the country is not significantly high with a maximum of 1,129 mm in Wangdue and a minimum of 889 mm in Zhemgang. However, there is a large variation in rainfall with the maximum reliable rainfall of 4,907 mm in Sipsu and 457 mm per annum in Paro. Of the total 20 stations, 8 stations have less reliable rainfall than potential evapo-transpiration while 5 stations have more reliable rainfall than ETo. The graphical comparison of reliable rainfall with ETo is presented in Figure 7.1 .The remaining 7 stations have more or less equal reliable rainfall and ETo. For planning perspective, irrigation is more important in those locations where reliable rainfall is less than ETo.

Table 7.11: 80% reliable rainfall of representative station

Station\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bhur	14.2	26.7	68.8	216.5	376.2	883.8	1127.5	850.6	548.6	172.7	13.6	9.5	4308.7
Chamkhar	4.9	10.1	28.1	57.4	79.7	93.1	133.8	126.5	83.4	55.8	4.7	2.0	679.6
Dagana	5.9	19.1	23.4	57.5	111.0	189.2	187.4	182.4	153.0	67.4	4.5	3.1	1004.0
Damphu	7.6	11.9	28.5	51.3	87.6	211.7	310.1	225.6	138.1	67.6	3.3	4.5	1147.8
Deothang	11.7	31.5	79.9	247.7	393.0	753.9	716.8	468.2	363.1	142.6	13.0	6.5	3227.9
Gasa	14.1	20.6	46.1	55.8	100.0	171.4	249.1	200.1	109.7	77.1	21.5	7.6	1073.0
Kangma	9.7	21.5	43.5	92.0	107.3	172.4	223.1	193.3	108.1	67.8	4.3	4.3	1047.4
Lhuntse	3.3	18.5	22.4	45.8	71.7	56.2	94.4	86.1	50.0	49.9	8.6	1.5	508.4
Mongar	4.6	11.1	31.1	71.1	82.0	117.7	164.3	140.2	95.5	63.5	2.7	2.6	786.3
Namjeyling	10.4	14.2	25.5	46.7	62.9	108.8	155.3	148.5	106.3	58.6	2.2	3.5	742.9
Paro DSC	5.9	8.8	14.4	22.3	40.4	58.5	120.5	79.3	62.2	35.5	6.4	2.8	457.0
Pemagatshel	10.6	26.7	77.3	109.2	139.6	272.8	382.1	239.2	156.6	101.0	18.1	8.2	1541.4
Phuentsholing	13.0	23.3	55.8	159.9	285.2	628.4	669.0	553.9	317.8	117.6	9.3	8.5	2841.7
Punakha	10.1	16.6	9.7	29.8	59.3	97.1	102.1	96.8	63.2	30.0	2.9	2.6	520.1
Simtokha	5.5	8.5	13.8	22.3	40.1	82.1	120.8	105.6	56.2	37.6	1.4	3.2	497.1
Sipsu	19.1	38.9	85.7	304.7	547.7	954.9	1166.7	957.7	595.1	195.4	25.7	15.2	4906.8
Trashi Yangtse	9.8	22.9	48.0	91.9	120.5	160.8	206.9	201.3	138.1	65.7	12.0	4.4	1082.3
Trongsa	6.7	13.2	39.1	82.0	120.3	144.5	187.1	182.4	116.4	56.0	6.7	5.1	959.5
Wangdue	7.2	8.3	14.3	36.5	53.8	91.3	123.5	116.6	78.8	39.1	5.8	3.1	578.3
Zhemgang	10.6	19.5	37.9	59.9	113.3	206.7	272.3	192.2	154.8	69.0	6.2	5.9	1148.3

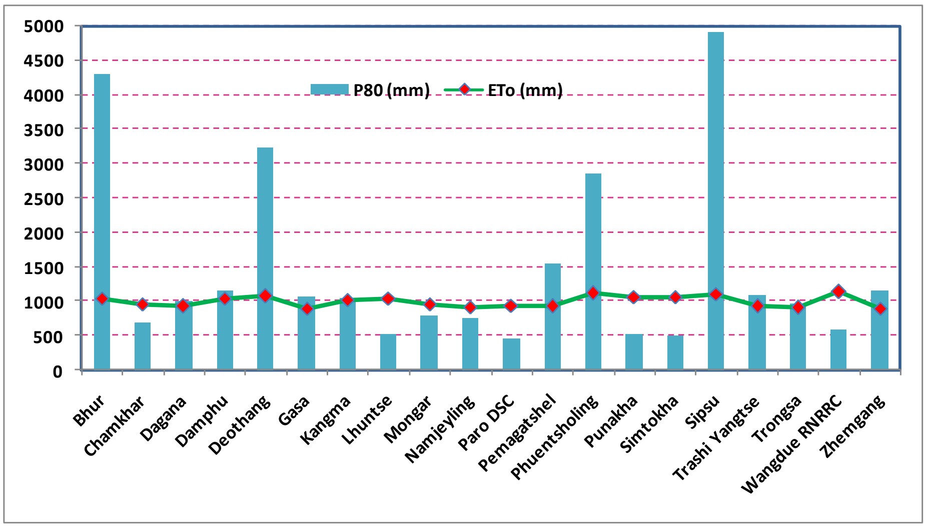
Table 7.12 : Effective rainfall corresponding to representative stations

Station\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Bhur	0.0	6.0	31.3	149.2	277.0	683.1	696.0	656.5	414.9	114.2	0.0	0.0	3028.2
Chamkhar	0.0	0.0	6.9	24.4	39.8	50.5	83.1	77.2	42.7	23.5	0.0	0.0	348.1
Dagana	0.0	1.5	4.1	24.5	64.8	127.4	125.9	121.9	98.4	30.5	0.0	0.0	599.0
Damphu	0.0	0.0	7.1	20.8	46.0	145.4	224.1	156.5	86.5	30.6	0.0	0.0	717.0
Deothang	0.0	8.9	39.9	174.2	290.4	579.1	549.4	350.6	266.5	90.1	0.0	0.0	2349.1
Gasa	0.0	2.4	17.6	23.5	56.0	113.1	175.3	136.1	63.8	37.7	2.9	0.0	628.4
Kangma	0.0	2.9	16.1	49.6	61.8	114.0	154.5	130.7	62.5	30.7	0.0	0.0	622.8
Lhuntse	0.0	1.1	3.5	17.5	33.4	23.7	51.5	44.9	20.0	19.9	0.0	0.0	215.5
Mongar	0.0	0.0	8.7	32.9	41.6	70.2	107.5	88.1	52.4	28.1	0.0	0.0	429.5
Namjeyling	0.0	0.0	5.3	18.0	27.7	63.0	100.2	94.8	61.0	25.2	0.0	0.0	395.2
Paro DSC	0.0	0.0	0.0	3.4	14.2	25.1	72.4	39.4	27.3	11.3	0.0	0.0	193.1
Pemagatshel	0.0	6.0	37.8	63.3	87.7	194.3	281.7	167.4	101.2	56.8	0.9	0.0	997.1
Phuentsholing	0.0	4.0	23.5	103.9	204.2	478.7	511.2	419.1	230.2	70.1	0.0	0.0	2044.9
Punakha	0.0	0.0	0.0	7.8	25.6	53.6	57.7	53.5	27.9	8.0	0.0	0.0	234.1
Simtokha	0.0	0.0	0.0	3.4	14.1	41.7	72.6	60.5	23.7	12.6	0.0	0.0	228.6
Sipsu	1.5	13.4	44.6	219.8	414.1	739.9	774.4	742.2	452.1	132.3	5.4	0.0	3539.7
Trashi Yangtse	0.0	3.7	18.8	49.5	72.4	104.6	141.5	137.0	86.5	29.4	0.0	0.0	643.4
Trongsa	0.0	0.0	13.4	41.6	72.3	91.6	125.7	121.9	69.1	23.6	0.0	0.0	559.2
Wangdue	0.0	0.0	0.0	11.9	22.3	49.0	74.8	69.3	39.0	13.5	0.0	0.0	279.8
Zhemgang	0.0	1.7	12.7	25.9	66.6	141.4	193.8	129.8	99.8	31.4	0.0	0.0	703.1

7.2.6 Crop coefficients

The values of crop coefficients (Kc) serve as an aggregation of the physical and physiological differences between crops and reference crop as defined earlier. The factors that determine the Kc are crop type, climate conditions, soil evaporation, and crop growth stages (namely initial stage, crop development stage, mid-season stage and late season stage). Crop coefficients of the crops selected for this NIMP are derived from FAO's Irrigation and Drainage Manual no. 56 (FAO, 1998). ET_{crop} have been calculated accordingly.

Figure 7.1: Comparison of reliable rainfall with ET0



7.2.7 Water application adjustments

The main water adjustments to consider for assessing irrigation requirements are land preparation requirements, deep percolation losses, and open water evaporation. Land preparation requirement is essential only for paddy as other crops do not require any initial watering for land preparation. It is considered that sufficient soil moisture is available for non-paddy crops that follow a paddy crop in the same field. Land preparation requirements per 15 day period are presented in Table 7.13

Table 7.13: Land preparation requirements (in millimeters)

15-day period	1st	2nd	3rd	4th
Pre-monsoon paddy	75	75	50	50
Monsoon paddy	55	50	50	50

Source: PDSP (1990)

Deep percolation losses are accounted only for paddy crop and depend on soil types (Table 7.14). Most of the irrigation fields in Bhutan lie on a sloping terrain and soils are mostly sandy clay. Due to lack of proper soil profile data for each irrigation zone, deep percolation losses for the NIMP have been taken as being 5 mm per day. Similarly open water evaporation (Eo) data are available for six Class-A stations only. For other stations similar altitude data are used. The adopted figures of Eo for this NIMP range from 1.5 mm per day in January to 5.5 mm per day in May and June.

Table 7.14: Deep percolation losses (in millimeters)

Soil texture	Newly irrigated	Long term irrigated
Sand, loamy sand	> 20	>20
Sandy loam	20	10
Very fine sandy loam, loam silty loam, sandy clay loam	20	5
Silty clay loam, clay loam silty clay, clay	5	2

Source: PDSP (1990)

7.2.8 Irrigation system efficiency

Water use efficiency is the most important irrigation system aspect to be considered in assessing water demand. The efficiency is the relation between quantity of water taken in for irrigation purpose and the quantity of water that finally is applied in the field at the root zone of the plant. Irrigation efficiency normally consists of three parts, each affected by a set of conditions: conveyance efficiency, distribution efficiency and field application efficiency.

Conveyance efficiency relates to the main and secondary canals and is dependent on seepage losses, management efficiency and losses due to irrigation turns (rotation). Conveyance efficiency is considered to be between 70% and 80%. Distribution efficiency is dependent on canal seepage, wetting and drying of canals, leakage at canals and management efficiency. Distribution efficiency is considered to be between 70% and 80%. Irrigation field application efficiency is expressed as the ratio of water stored in the root zone to the amount of water applied. Field application efficiency also depends upon the type of crops. For dry root crops, it is considered to be at 60% while for paddy it is up to 85%.

For the NIMP, conveyance and distribution efficiencies have been both considered at 75%. The field application efficiency is considered at 70% with the overall irrigation system efficiency at 39%.

7.2.9 Irrigation water requirement

Irrigation water requirement has been calculated for each irrigation zone based on all the above mentioned considerations and parameters. The computed water requirement per unit of land area (ha) is presented in Table 7.15. This is based on the detailed irrigation water requirements for each station / district corresponding to the cropping patterns presented earlier.

Table 7.15: Irrigation water demands (l/s/ha)

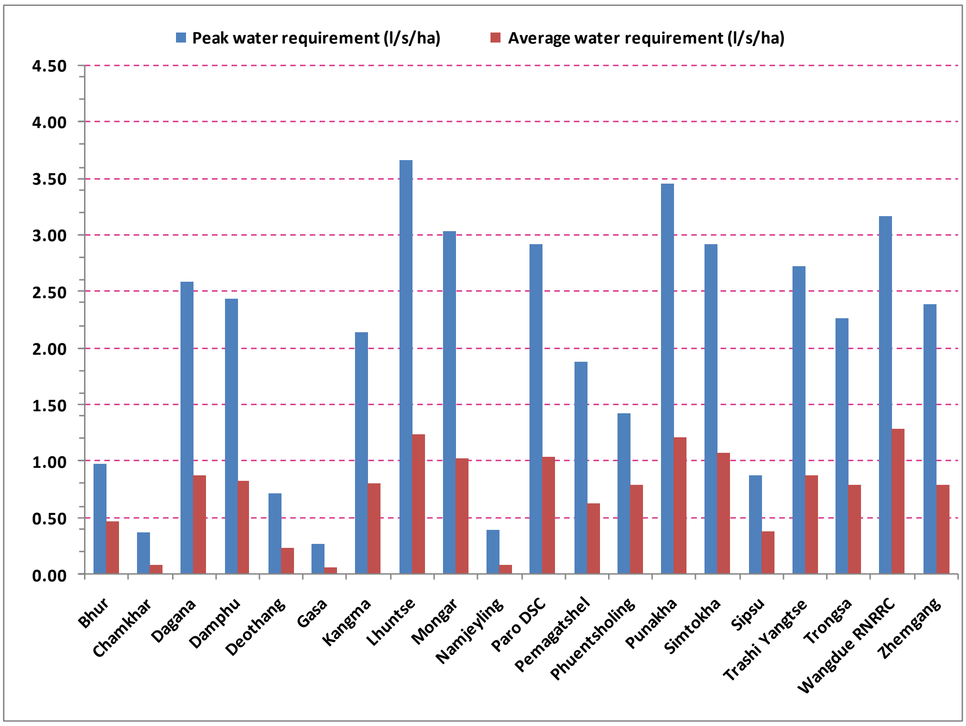
Station\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bhur	0.57	0.85	0.63	0.25	0.95	0.25	0.00	0.00	0.23	0.97	0.48	0.27
Chamkhar	0.00	0.00	0.11	0.26	0.36	0.19	0.02	0.00	0.00	0.00	0.00	0.00
Dagana	0.28	0.32	0.25	0.06	1.71	2.59	1.59	1.14	1.32	0.83	0.08	0.26
Damphu	0.33	0.37	0.31	0.09	1.89	2.43	0.88	0.88	1.36	0.91	0.09	0.29
Deothang	0.27	0.38	0.35	0.00	0.38	0.00	0.00	0.00	0.08	0.71	0.31	0.21
Gasa	0.00	0.00	0.06	0.24	0.26	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Kangma	0.36	0.39	0.37	0.09	1.45	2.13	1.11	0.91	1.28	0.90	0.09	0.40
Lhuntse	0.32	0.36	0.27	0.09	2.08	3.67	2.78	1.94	1.96	0.98	0.08	0.26
Mongar	0.28	0.35	0.25	0.05	1.95	3.03	1.81	1.50	1.68	0.91	0.08	0.26
Namjeyling	0.00	0.00	0.11	0.29	0.38	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Paro DSC	0.23	0.34	0.45	0.30	1.88	2.92	1.76	1.59	1.51	0.97	0.07	0.31
Pemagatshel	0.29	0.29	0.14	0.01	1.60	1.88	0.38	0.66	1.17	0.74	0.08	0.27
Phuentsholing	0.56	0.90	0.74	0.37	1.36	1.17	0.37	0.29	1.42	1.42	0.52	0.19
Punakha	0.29	0.35	0.31	0.13	2.15	3.45	2.43	2.00	1.99	1.04	0.08	0.26
Simtokha	0.27	0.38	0.51	0.34	1.93	2.92	1.88	1.57	1.61	1.01	0.08	0.34
Sipsu	0.58	0.82	0.58	0.20	0.59	0.06	0.00	0.00	0.08	0.87	0.47	0.19
Trashi Yangtse	0.28	0.30	0.19	0.02	1.75	2.71	1.53	1.08	1.34	0.85	0.08	0.25
Trongsa	0.24	0.32	0.35	0.13	1.47	2.26	1.23	0.92	1.17	0.87	0.07	0.32
Wangdue	0.23	0.42	0.72	0.53	1.89	3.17	2.59	2.00	1.93	1.35	0.31	0.18
Zhemgang	0.27	0.29	0.21	0.05	1.72	2.38	1.06	1.01	1.22	0.82	0.08	0.25

7.2.10 Water requirement analysis

Unlike almost even distribution of ETo across the representative stations and related irrigation zones, water requirement distribution is uneven across the country. The peak per unit water requirement varies from 0.30 l/s/ha to 4.22 l/s/ha with the maximum value in Punakha and minimum value in Gasa. However, Chamkhar, Gasa, and Namjeling represent the cool temperate high mountain zone where proposed cropping patterns require less irrigation, and, hence may not be significant to consider for water requirement assessment. The warm temperate high altitude zone and the dry sub-tropical medium altitude zone have higher peak water requirements based on the proposed cropping patterns. In the humid sub-tropical mid altitude zone only two stations are available for water requirement assessment: Deothang and Wangdue RNRRC. The peak water requirement of these two stations varies significantly as Deothang shows 1.0 l/s ha of peak water requirement while Wangdue has 3.40 l/s/ha (Figure 7.2).

This is mainly due to rainfall contribution. In Deothang annual reliable rainfall is 3,228 mm while it is 578 mm in Wangdue RNRRC. Due to this high rainfall range, the water requirement varies significantly between these two stations despite similarity in ETo. The ETo of Deothang is 1069 mm per annum while in Wangdue it is 1129 mm.

Figure 7.2 : Peak and average water requirement (l/s/ha)



7.3 Climate change and future crop water demands

As noted above, present crop water requirements have been computed through the calculation of ET_0 using observed monthly climatic data of 20 numbers of "class A" stations that cover all the 20 districts and agro-ecological zones of Bhutan. The climatic data that have been used for this purpose are max temp, min temp, rainfall, relative humidity, wind speed and sunshine duration[44].

In the context of expected climate change, projected climatic data have been used for computing future crop water requirements for the NIMP. The following methods have been used for this purpose (details are provided in the ADB TA Climate Change Report- TA 8623 R5, 2016).

- The first set of projected data (rainfall and temperature) is derived from Aphrodite data base[45] using the latest scenarios from global climate models (CMIP5) under RCP 4.5 and RCP 8.5. Using Aphrodite data, reference crop evapo-transpiration (ET_0) have been generated for the periods 2010-2030 and 2060-2090 with the help of SWAT model (Soil Water Assessment Tool).
- Second set of data has been generated using the observed data from 8 stations from 1990-2005

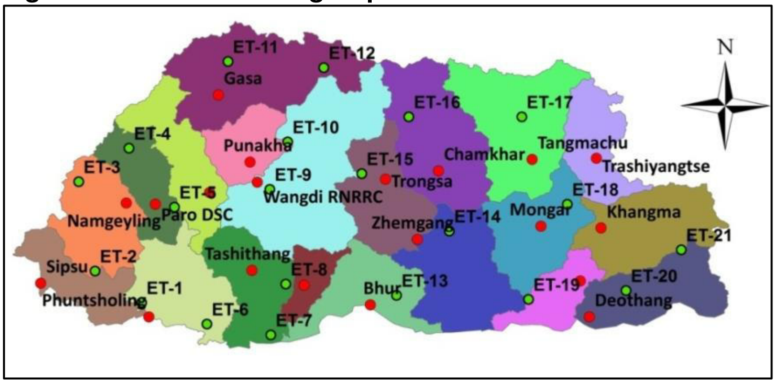
The first set of data that are derived from the Aphrodite data corresponds to the 21 grid points that are represented by small dots marked as ET-1 to ET-21in Figure 7.3 (TA8623 R4, 2015). While the other dots represent the locations of 20 number of Class A Climatic stations, whose data are used in computing present ET_0. It is to be noted that the geographical locations of the 21 grid points do not

44 Most stations have data from 1996 to 2014 which are averaged to get long-term monthly data for Cropwat-8.

45 Aphrodite data is the data developed with the help of high-resolution grid dataset which in turn are created primarily with data obtained from a rain-gauge-observation network. Aphrodite data refers to the "Asian Precipitation Highly Resolved Observational Data Integration towards Evaluation of Water Resources (APHRODITE)".

match with those of the class A stations. Theoretically, although each of these stations is supposed to represent a certain area, it is not certain whether projected ET_0 using Aphrodite data can be compared with the present ET_0 computed with the observed data. This is particularly true in the case of Bhutan, as the country exhibits diverse climatic parameters due to its terrain and wide altitudinal variations.

Figure 7.3: Locations of grid points and class A climatic stations



Source: TA 8623 R4 (2015) for 21 ET stations

However, attempts were made in comparing ET_0 of some of the grid points with that of the class A stations that are physically close to one another. For this, four stations namely Bhur, Wangdue, Phuntsholing, and Mongar were found suitable. Figure 7.4 presents the observed and projected ET_0 of the class A stations and grid points belonging to these locations. Observed ET_0 are the present value calculated from the data of class A stations, while ET 10-30 and ET 60-90 are projected $ET_0$for 2010 to 2030, and 2060-2090 respectively.

Figure 7.4: ET0 for grid and class A stations with observed and projected data

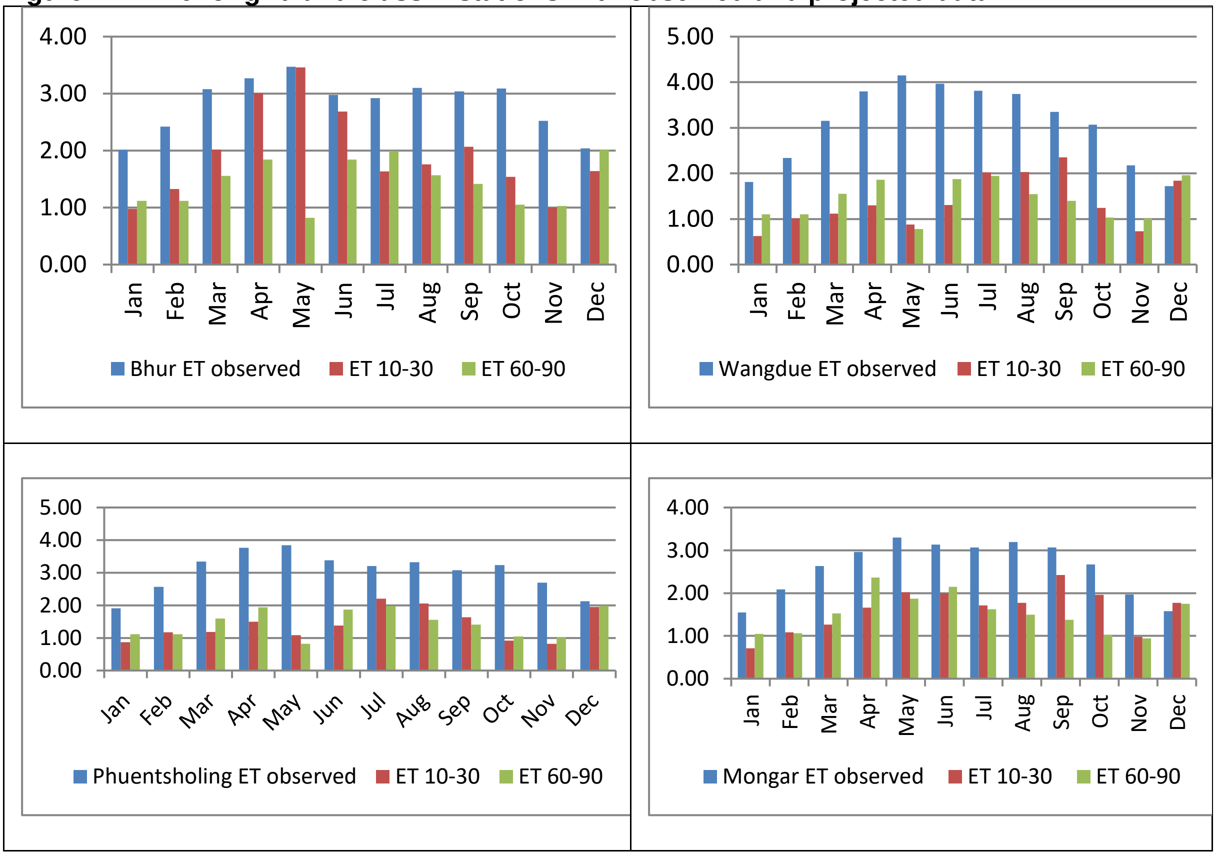


Figure 7.4 suggests that the projected ET_0 for 2010-2013 are far below the observed ET_0, though good matches can been seen between ET 10-30 and ET 60-90.

This suggests that the Aphrodite data is biased against the observed data.

Furthermore, analysis of the second set of future climatic data that were generated using observed data of 8 climatic stations[46] suggests that these data do not provide satisfactory results as changes are seen only in the western part of Bhutan[47].

Recognizing the above mentioned methodological constraints in projecting climatic data and also due to complex physiographic features of Bhutan, crop water requirement computed from the observed values have also been used for projecting future irrigation requirements. The logics are two folds. Firstly, as the NIMP has a planning horizon of 15 years, there may not be substantial changes in climatic parameters influencing crop water requirement during this time period. Secondly, the supply side of water for irrigation management is quite good, and as of now water constraints have not been noticed in any of the planned irrigation development locations. So, slight adjustment in future irrigation requirements due to climate change, if any, can be managed within the limitation of the present water supply situation.

7.4 Targeted areas for irrigation development

Targeted areas for irrigation development are determined by food crop production requirements, which in turn are shaped by the food and nutritional security policy of the Royal Government of Bhutan. This is explained below.

7.4.1 Food security and crop production targets

As noted above, food and nutritional security has been one of the main policy objectives of the Royal Government of Bhutan. Often, this is equated with calorie intake rather than a balanced diet of nutritious food. In Bhutan, although the national average calorie intake exceeds 2500 Kcal/person/day, in the worst-off areas this figure does not reach 1900, or only 85-90% of the 2124 Kcal/person/day set as the minimum required (FNS policy, 2014). RNR statistics (2012) indicate that in 2011 daily per capita food supply reached to 2657 Kcal.

Balance diet includes a combination of cereals, fruits & vegetables, oil & fat, and livestock products (meat, milk, and eggs). Average consumption of livestock products for protein, vitamins, and minerals in the Bhutanese diet is lower than what is required for good health (FNS policy, 2014). But, its demand and production are increasing. In 2009, the national production of livestock products met 35% of the total demand in the country, while in 2011 about 85% of the demand was met (FSN policy 2014). Unlike this, the domestic production of oil and fat is negligible and almost 100% is imported. The situation and trend for fruits and vegetables is better as most of them are produced locally. Fruits such as apples and oranges are exported.

Food self-sufficiency has also been one of the indicators of the national food production system, and one of the goals of the RNR sector relates to increasing food self-sufficiency through domestic production. While doing so, food self-sufficiency has been defined as “a household’s or country’s ability to provide adequate food through domestic production during the specified reference year” (RNR statistics, 2012).

Past data on the level of food self-sufficiency have been examined in this context, which are summarized in Table 7.16

[46] It is to be noted that only these 8 stations has appropriate 30 years continuous time series data, though majority of these satiations are categorized as class B stations.

[47] Personal communication with the TL, TA 8623

Table 7.16 : Level of food self-sufficiency as reported by several plans and policies

SN	Related documents	Level of food self-sufficiency (%)					
		Achieved			Target		
		Year	All cereals	Paddy	Year	All cereals	Paddy
1	10th FYP						65
2	11th FYP(GNHC,2014pp 48[48])			50			
3	11th FYP (GNHC, 2013c)	2013	64		2018	75	
4	RNR statistics 2012	2011	63.6	51.3	2012	69	53
5	FNS policy 2014[49]	2011	69.0	53.0			

Data presented by RNR statistics (2012) and 11th FYP are close to one another. So, the NIMP considers that the prevailing level of food self-sufficiency for the year 2011 amounts to 64% for all cereals (including paddy), and 51% for paddy only. As the production of cereals has not increased since 2011 (Figure 1.14 to 1.19), it is assumed that the present level (2014) of food self-sufficiency remains the same. In this context, the 11th FYP target of meeting 75% cereal self-sufficiency by 2018 seems to be unrealistic.

Recognizing above situation, the NIMP aims to achieve a target of 75% self-sufficiency for paddy and of 80% for all the cereals by 2032.

Official statistics published by the Ministry of Agriculture and Forest indicate a paddy production of 78,203Mt in 2011, 78,014Mt in 2012 and 75,228 Mt in 2013. Production of paddy in 2014 also remained in the same range (DOA AS 2014). The estimated population of the country during the same years was about 708,265, 720,679 and 733,004 inhabitants respectively. These figures suggest an average annual production of paddy of about 107 kg per person across the 3 years.

As noted above, the present level of paddy production is just enough to meet 51% of the national demand. With the expected population of about 900,000 in 2032, the country thus requires to produce about 145,000 Mt of paddy for meeting 75% rice self-sufficiency. This means that Bhutan needs to increase its production by almost two folds compared to the present level of production.

Likewise, the average annual domestic production of cereals (including paddy) is about 170,806 Mt[50]. This represents 237kg /person /year, corresponding to about 64% of the national demand. This means that in order to meet the target of 80% cereal self-sufficiency by 2032, Bhutan needs to produce about 267,000 Mt. of cereals.

Further, the livestock sector of the country also needs cereals for achieving balanced diet of nutritious food as proposed by the food and nutritional security policy of Bhutan. Recognizing this need, it is assumed that about 20% of the non paddy cereals (about 25,000 Mt), which include maize mainly would be required for livestock feeds[51]. With this estimation, the total demands of non paddy cereals will be about 147,000 Mt

The above estimation is based on linear interpolation of available data, which does not take into account the likely change in food habits. In reality, however, food habit is changing. Experiences of south Asian countries suggest that with slight increase in per capita income, consumption of livestock products and wheat will increase, while the consumption of rice and other cereals will decrease (ADS-Nepal, 2013). Bhutan is also expected to follow this trend, and thus the present rate of rice consumption may somewhat be reduced in the future. However, the likely reduction in rice consumption is not taken into account in computing requirement of irrigated areas for food production. This means that the irrigated

48 Major achievement of 10th Plan (2008-2013)
49 Also refers to RNR statistics 2012
50 Average of 2009-2013 production (Refer DOA statistics)
51 Presently, Karma feed imports 17,000 Mt of cereals and others ingredients for livestock feeds. In this sense, targeted production of 25,000 Mt of maize and others (by 2032) for livestock feeds seems appropriate

area estimated on the basis of food production requirement may actually be on the higher side. This will further increase the level of food self sufficiency against the targeted value.

Besides cereals, other crops to be promoted under the NIMP include oilseeds, vegetables, legumes and fruits.

7.4.2 Targeted irrigated areas

Targeted irrigated areas are estimated based on planned production volumes of irrigated crops, which in turn depend on expected crop yields. This is explained below.

Average paddy yield over the past three years (2011-2013) was about 1.454 Mt/acre, while its yield in 2014 was 1.57 Mt/acre (DOA AS, 2014). With the development of irrigation facilities and improved agricultural services, it is expected that paddy yield will increase by 10% each year of the five year planned period. With this expectation, cumulative increase in paddy yield by 2032 will be 1.93 Mt/acre (or 4.78 Mt/ha).

This target however is less than the target set by the 11th five year plan, which aims to increase the yield of paddy from 1.3 Mt/acre to 2.0 Mt/acre by 2018. The 11th FYP target seems to be too ambitious. Hence, the realistic expectation might be 1.93 Mt/acre.

Likewise, present weighted average yield of cereals other than paddy is 1.072 Mt/ac. With irrigation facility, this yield is also expected to increase by 10% each year of the five year planned period leading to a cumulative yield of 1.43 Mt/ac by 2032.

With the above assumptions on crop yields, Table 7.17 presents areas required to be irrigated for meeting targeted production of paddy and other cereals.

Table 7.17: Required irrigated areas for meeting targeted production

Crop	Production required by 2032 (Mt)	Present average production (Mt) (2011-2013)		Likely production from rain-fed farming by 2032	Future scenario: Irrigated agriculture		
		Irrigated	Rainfed		Additional production required (Mt)	Yield (Mt/ac)	Cropped areas (ac)
Paddy	145,000	77,149			67,851	1.93	88,168
Other cereals	147,000		93,657	116,350[52]	49,580	1.43	30,650

Note: Other cereals includes maize, wheat, buckwheat, barley, millet

Table 7.17 suggests that with the targeted yield of 1.93 Mt/acre, and assuming that wet season paddy covers 85% of the area, total irrigated land required to produce 145,000 Mt of paddy will be about 88,000 acres. The present irrigated area (Chhuzhing) is reported to be 64,248 acres. This means, an additional area of about 24,000 acres will have to be brought under irrigation.

Once irrigation infrastructures are developed to produce paddy over 88,000 acres, other non paddy cereals can be cropped in the same fields during the winter and spring seasons when paddy is not cropped. Thus, the targeted areas of 30,650 acres can be easily achieved by allowing partial use of paddy fields for other cereals (maize, wheat, buckwheat etc) during the winter and spring seasons. Likewise, ample irrigated land will also be available for cultivating other crops such as permanent crops (fruit orchards) and cash crops (vegetables, oilseeds, legumes, etc.) to meet their production targets.

Based on the above estimations, the NIMP aims to develop new irrigation facilities on 27,000 acres of land with 3,000 acres (about 12%) as an extra provision for unforeseen conditions. This target will be achieved through four main irrigation development thrusts, as presented below.

[52] Assuming 7.5% increase in yield of rain-fed cereals in each five year plan period

Thrusts for irrigation development	Additional areas under irrigation (ac)
Improvement of existing irrigation systems with three subcomponents namely modernization, renovation and bottleneck repair (defined later) covering an area of 64,000 acres (excluding small systems less than 15 acres). It is expected that this improvement will increase the irrigated area by about 8,000 acres. The related project is named as "**Existing Irrigation Improvement Project (EIIP)**"	8,000
Development of new surface irrigation in the middle mountains and valleys with a focus on cereal and high value crops. The related project can be named as "N**ew Hill Irrigation Development Project (NHIDP)**"	4,000
Development of new dry land irrigation with appropriate technologies mainly for irrigating Kamzhing with a focus on high value crops like orchards, pulses, oilseed, vegetables etc. The related project can be named as new "D**ry Land Irrigation Development Project (DLIDP)**"	4,000
Development of new irrigation systems in the three southern districts for converting about three fourth of the rain-fed Chhuzhing (15000 acre) into irrigated Chhuzhing. The related project can be named as "W**et Subtropical Irrigation Development Project (WSIDP)**"	11,000
Total	27,000

8. Irrigation development roadmap and likely projects

The road map for the development of irrigation follows activities of a project development cycle like planning, study, implementation, operation (management) and M&E that include both the structural and non-structural components. For NIMP, these activities are grouped into three categories of interventions. These are: i) project studies and preparation, ii) project implementation and development, and iii) project management and operation. Table 8.1 summarizes these interventions, and paragraphs below further describe them.

Table 8.1: Irrigation development roadmap and key projects

SN	Project group	Description
1	Project studies and preparation (PSP)	This includes several sectoral studies and project specific studies starting from prefeasibility to detail design
2	Project implementation and development	This includes infrastructural and land development projects as described below
2.1	Improvement existing irrigation systems	This will include improvement of existing community managed irrigation systems (CMIS) covering an area of about 64,000 acres. Targeted expansion of irrigated areas is 8,000 acres
2.2	Development of new irrigation systems	This includes development and implementation of three types of irrigation development projects. These are; (i) Dry Land Irrigation Development Projects (4000 acre), (ii) New Hill Irrigation Development Project (4000 acre), and (iii) Wet Subtropical Irrigation Development Project (11,000 acre)
2.3	Land development and agricultural mechanization	This includes three components: (i) land development, (ii) on farm trail development, and (iii)agricultural mechanization
3	Project management and operation	This includes two components: (i) Integrated crop and water management and (ii) Institutional strengthening and capacity building

8.1 Project studies and preparation (PSP)

The project studies and preparation (PSP) will include two components. The first component relates to sectoral studies and mapping, while the second component relates to project specific studies starting from pre-feasibility to detail design. Followings are the proposed studies under PSP.

- Irrigation sector institutional study: this study will examine central, district and local level irrigation institutions for designing efficient organizational setup to implement the NIMP.
- Groundwater investigation in the river valleys and low altitude wet sub-tropical areas.
- High resolution mapping of the cultivated land.
- Hydrological studies for assessing water resources of un-gauged catchment.

- Preparation of irrigation development projects (from pre-feasibility to detail design) covering an area of about 77,000 acres[53].

The estimated cost of PSP is about USD6.40 million. Chapter 13 provides details on cost.

8.2 Project implementation and development

8.2.1 Existing Irrigation Improvement Project (EIIP)

The Existing Irrigation Improvement Project (EIIP) will improve the community managed irrigation systems that were developed by farmers since long. This will be done through three modes of interventions, namely i) modernization, ii) renovation and iii) bottleneck repair, which are further defined under the forthcoming chapter (Chapter 12) on “prioritized irrigation development projects and sub projects”. EIIP will be implemented in conjunction with (a) Land Development and Agricultural Mechanization Project, (b) Integrated Crop and Water Management Project, and (c) WUA institutional strengthening project.

Present states of the CMIS are poor. Leaking earthen canals and their frequent damage by landslides, sedimentation in the canal head reach, lowering of river bed, insufficient water at the source, inappropriate structures, and increasing competition over the use of water are the common problems of these irrigation systems. These systems are labor intensive for their maintenance.

Despite the fact that they were fairly sustainable in the past, due to changing socio-economic situation of water users, community management of the CMIS are becoming increasingly difficult. As a result, about 10% of them are already dysfunctional. In view of hardship being faced by the mountain communities in maintaining their traditional irrigation systems, external interventions seem justified. In the absence of such interventions, agricultural productivity may further decrease. This is evidenced by the fact that the cropped area under irrigation has already declined from 62,360 acres in 2005 to 48,361 acres in 2013.

A couple of donor funded projects are already providing infrastructural support to these irrigation systems. However, most of the present support is being made on piecemeal basis, and effectiveness of this support is difficult to judge.

The Existing Irrigation Improvement Project thus aims to improve existing irrigation systems with a view to enhance their performance and at the same time bring additional 8,000 acres of rain-fed land under irrigation through the expansion of the existing irrigation systems. Besides this, EIIP will also help in increasing the yields of the cereal crops and the overall cropping intensity of existing irrigation systems.

The estimated cost of EIIP is USD31.920 million

8.2.2 Development of new irrigation system

Depending on the choice of technology and geographical location, three types of new irrigation development projects are proposed.

8.2.2.1 Dry Land Irrigation Development Project (DLIDP)

The drying-up of the water sources in the upper watershed of the Bhutan river system has been one of the main problems in managing irrigation and domestic water supply. The situation will further aggravate with the anticipated impacts due to climate change.

The Dry Land Irrigation Development Project (DLIDP) aims to address this problem by providing access to more reliable water resources for irrigating dry land (Kamzhing) located in the upper watersheds of

53 New irrigation 27,000 acres, rehab 24,000 acres, and modernization 26,000 acres

Bhutan and which are particularly vulnerable to climate change. Beside irrigation, the project will also provide reliable domestic water supply for communities living in these areas.

Access to and reliability of water resources will be improved through a participatory program of integrated catchment management to increase surface water storage and groundwater recharge. The project will include (i) protection of the catchment areas surrounding the water sources and preparation and implementation of the water source catchment management plans, (ii) treatment of gully erosion and slope / landslide stabilization that threaten the water sources, water infrastructure, and beneficiary communities; (iii) construction of water collection chambers, spring boxes or infiltration galleries; (iv) construction of irrigation canals, water conservation ponds and storage tanks for irrigation, and (v) development of irrigation systems like drip, sprinkler, and pipelines for direct water application in the fields.

Water storage will help sustain the use of limited water during the dry season, thereby increasing the area irrigated during the dry season. Catchment improvement measures will help to stabilize or increase the yield of the water sources.

As a result of the project, the springs or surface water sources are expected to become more reliable, with water yield either remaining stable or increasing. Thus, the project's outcome will be that the target communities will have more reliable water supplies during the dry season.

The project (DLIDP) will comprise small and micro irrigation systems covering an area of about 4,000 acres of Kamzhing located in the high elevation watershed areas of the middle mountains and valleys of Bhutan. This project will be implemented in association with the (a) Land Development and Agricultural Mechanization Project, (b) Integrated Crop and Water Management, and (c) WUA capacity building projects.

The estimated cost of DLIDP (4,000 acres) is USD7.2million.

8.2.2.2 New Hill Irrigation Development Project (NHIDP)

The New Hill Irrigation Development Project (NHIDP) aims to develop new irrigation systems by taping water from new water sources for irrigating both the Kamzhing and Chhuzhing, parts of which presently depend on nearby seasonal streams[54]. The main difference between the Existing Irrigation Improvement Project (EIIP) and the New Hill Irrigation Development Project (NHIDP) is that the EIIP aims to further develop irrigation systems with existing water sources, while NHIDP aims to tap water from new perennial sources so as to increase irrigation on Chhuzhing, and bring new Kamzhing under irrigation. Thus, NHIDP primarily aims for diversification of water sources for expanding irrigation areas.

While doing so, the NHIDP will adopt several technologies to access new water sources. These may include open gravity canal, piped canal, and water lift from a perennial river located downhill.

The NHIDP will include components on (a) water acquisition system (diversion intake or pumps), (b) conveying canals, (c) water distribution canals and (d) command area development. With these components in place, the target communities will be expected to receive reliable irrigation services round the year. This project will be implemented in association with the (a) Land Development and Agricultural Mechanization project, (b) Integrated Crop and Water Management, and (c) WUA capacity building projects.

54 Usually, land areas in mountainous terrain are heavily dissected by natural drains and gullies. In this situation, a village or an area would contain several patches of Chhuzhing with independent irrigation systems that receive water from adjoining seasonal streams whose discharge virtually depends on the rainfall. In the past, though these seasonal streams used to supply fair amount of water for irrigating respective patches of Chhuzhing, they are now reported to be drying up due to several reasons. The situation may be further aggravated as a result of climate change.

The NHIDP aims to develop several new irrigation systems covering a total area of about 4,000 acres. The project will be country wide with the exception of parts of the low altitude wet sub-tropical areas in the southern foot hills of Bhutan (mainly areas under Samtse, Sarpang, and SamdrupJongkhar districts) for which a separate irrigation development project is proposed. Besides the development of new irrigation systems, NHIDP will also include revitalization of the dysfunctional irrigation systems, which have not been operating since many years[55].

The estimated cost of NHIDP (4,000 acres) is USD 5.88 million.

8.2.2.3 Wet Subtropical Irrigation Development Project (WSIDP)

The Wet Subtropical Irrigation Development Project (WSIDP) will cover the southernmost narrow strips of the low altitude wet sub-tropical foot hill areas of Bhutan[56]. The project (WSIDP) aims to develop new irrigation systems for irrigating rainfed Chhuzhing by acquiring water from new water sources. In this sense, the concept of WSIDP is very much similar to that of the New Hill Irrigation Development Project (NHIDP).

However, because of the unique agro-ecological characteristics of the targeted project areas[57], irrigation systems found in this area are referred to as “Foot Hill Schemes”, whose infrastructures and management practices differ considerably with the hill and valley bottom irrigation schemes. In this sense, the WSIDP is different from the New Hill Irrigation Development Project.

It has been reported that about 15,000 acres of rainfed Chhuzhing presently exist in the project areas (DOA 2013a). Of these, about 13,248 acres are found in the Samste District, while the remaining 1,146 acres and 1,020 acres are situated in the Sarpang and SamdrupJongkhar Districts respectively.

Of the 15,000 acres, the WSIDP aims to develop new irrigation systems that will cover an area of about of 11,000 acres. The WSIDP will include components on (a) water acquisition system (diversion intake or pumps), (b) conveying canals, (c) water distribution canals and (d) command area development. With these components in place, the communities in the project area will receive reliable irrigation services round the year. Besides developing new irrigation systems, WSIDP will also include revitalization of the dysfunctional irrigation systems, which are not operating since many years.

Like other projects, this project will also be implemented in association with the (a) Land Development and Agricultural Mechanization Project, (b) Integrated Crop and Water Management, and (c) WUA capacity building projects

The estimated cost of WSIDP (11,000 acres) is USD14.85 million.

8.2.3 Land development and agricultural mechanization

The Land Development and Agricultural Mechanization Project (LDAMP) will cover the whole of Bhutan, and it will be implemented in conjunction with other projects like Existing Irrigation Improvement Project, New Hill Irrigation Development Project, Dry Land Irrigation Development Project, and so on. The LDAMP will have three main components:

- Land development,
- Agricultural mechanization, and
- On farm trail development for farm machineries.

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55 As per water act, rebuilding of dysfunctional system is considered as new system. For this reason it is kept under NHIDP

56 The project mainly covers the SamdrupJongkhar, Sarpang and Samtse Districts

57 These strips of wet sub-tropical foothills constitutes of largest flat (or almost flat) land in the country.

8.2.3.1 Land development

Land development is one of the on-going programs of the 11th FYP. It includes all activities related to land development and management such as terracing, contour bunding, land consolidation, terrace widening etc. The NIMP proposes to implement land development component in about 8,000 acres of dry land areas that are to be brought under irrigation by several projects.

While the management of an irrigation system is the domain of the community concerned, land management within one's holding is a private affair. Recognizing this, the Land Development and Agricultural Mechanization Project will establish a guideline for developing privately owned landholdings, and subsequently implement land development activity under participatory approach.

The estimated cost of land development component of LDAMP is USD11.2 million

8.2.3.2 Agricultural mechanization

Agricultural mechanization includes the use of tools and machineries for various agricultural activities like land development, field ploughing, crop harvesting, grain threshing and so on. The NIMP through LDAMP recognizes the importance of agricultural mechanization in the context of increasing scarcity of agricultural labor, and thus aims to make the provision of farm machineries for local communities.

In Bhutan, mechanization of irrigated agriculture was initiated in 1983 with the introduction of the power tillers through the KR II Japanese Grant. Since then the Agriculture Machinery Centre (AMC) was also established with the mandate to promote labor saving technologies in the agriculture sector. Some of the advantages brought to the farmers through agricultural mechanization relate to saving in labor and cost for land preparation. It is to be noted that power tillers can plough 4 times the area as compared to bullock ploughing, with a cost reduced by 50%. Likewise, substantial reduction in labor requirement is reported with the introduction of small farm equipment for transplanting, weeding, harvesting and threshing (AMC, 2012).

As of now, the Agriculture Machinery Centre (AMC) is the only responsible government agency in Bhutan for supply, distribution, training and maintenance of small farm machinery. It provides services to local communities through its 4 regional offices. Involvement of the private sector in agriculture mechanization is still limited. Presently, all the technical backup services required by farming communities are provided by the AMC.

In 2011, the Department of Agriculture formulated a Farm Mechanization Strategy (FMS, 2011) for further developing agricultural mechanization in the country. The strategy outlined several policy principles. Involving the private sector is one of them, with the objective to (a) deliver the support services efficiently, (b) establish mechanism for renting out of machinery to farmers, and (c) establish repair and maintenance centres.

The LDAMP aims to support Farm Mechanization Strategy 2011 through following activities:

- Provision of farm machineries.
- Strengthening legally recognized water user associations which can possess, manage, and rent out farm machineries to their members (local communities) and collect revenues from rental services to be used for maintenance of the machines, and re-payment of the loans,.
- Strengthening the private sector for continuing maintenance support to farm machineries.

It is to be noted that the 11th FYP aims to increase areas under agricultural mechanization from 1,271 to 5,000 acres by 2018. Considering this target, the NIMP through LDAMP aims to mechanize agricultural activities on an additional 15,000 acres of irrigated land by 2032.

The estimated cost of agricultural mechanization of LDAMP is USD25.5 million.

8.2.3.3 On farm trail for farm machinery

The development of on farm trails is a pre-requisite for mechanization of irrigated agriculture. Such trails are proposed to be built along the canals. In a mountain terrain, main canals usually follow the contour lines, while branch canals go down the hills. The Land Development and Agricultural Mechanization Project (LDAMP) aims to develop "on farm trail" along these canals, especially utilizing their right of way. This will facilitate movement of small farm machineries within and between the farms.

Development of "on farm trail" will follow a participatory approach.

It is expected that with the development of the trails, small farm machineries will be able to be driven along the main canals and reach the fields. This component of the project will have two outcomes. Firstly, communities in the project areas will be able to plough their land using small tractors / power tillers, which in turn will reduce dependency on animal draught and farm labor. Secondly, canal banks will be reinforced, and labor dependency for irrigation system maintenance will also be reduced as small tractors can easily transport construction materials for maintenance as well as farm produce for marketing.

On farm trails will be about 2.5 meter wide tracks aligned along both the main and branch canals. While the trails along the main canals will follow contour lines, trails along the branch canals will follow hill slopes. These should be able to facilitate movement of hand driven power tillers along the hills. Space between two trails going down hills will be kept at about 250 m.

Following the target of agricultural mechanization, it is proposed that "on farm trails" will also be implemented over an area of 15,000 acres.

The estimated cost of "on farm trails" of LDAMP is USD1.5 million.

8.3 Project management and operation

8.3.1 Integrated Crop and Water Management Project (ICWMP)

Integrated crop and water management (ICWM) is a concept that combines the management of the irrigation system, on-farm water system, and crop production system. It aims to optimize agricultural production of an irrigation system, and at the same time ensures sustainability of the developed irrigation infrastructure. It is now widely recognized that increased agricultural production is not likely to be achieved only with interventions on the hardware (infrastructural) components of irrigation development. Activities under the Integrated Crop and Water Management Project (ICWMP) will include (a) identification of local needs on irrigated agriculture sector, and planning with the farmers in a participatory manner (b) adaptation of appropriate irrigation methods with respect to crops grown, (c) introduction of effective and equitable water allocation / distribution methods at system level, (d) introduction of new cash crops like winter potato, spring maize, and others (e) initiate agriculture extension services for agriculture intensification and diversification, improved agricultural practices for high yielding crop varieties, optimal plant nutrition and fertilizer practices, optimal and safe pest and weed management, crop rotation etc., (f) establish coordination with sectoral line agencies at all levels for the delivery of inputs and services, and (g) capacity building of water user groups and farming communities.

The ICWMP will be implemented through two different approaches. The first approach will follow the sector wide development of irrigated agriculture, while the second approach will be project specific. These are described below:

8.3.1.1 ICWMP through sector wide approach

Under this approach, the ICWMP will be implemented throughout Bhutan covering about one third of the proposed irrigated area, namely 30,000 acres. It is assumed that the results of this project will automatically propagate to remaining two third of the area through farmer-to-farmer training and observations, and thus benefits the entire country.

ICWMP will be implemented in conjunction with other infrastructural development projects like (a) Existing Irrigation Improvement Project (EIIP) (b) Dry Land Irrigation Development Project (DLIDP), (c) New Hill Irrigation Development Project (NHIDP), and (d) Wet Subtropical Irrigation Development Project (WSIDP). However, activities under this project will be initiated once the major infrastructure component is complete. It will be implemented jointly by the engineering and agriculture extension divisions of the Department of Agriculture.

The estimated cost of sector wide ICWMP is USD 15 million.

8.3.1.2 Taklai Integrated Crop and Water Management Project

The Taklai Integrated Crop and Water Management Project will be implemented in the Taklai irrigation system under a project specific approach.

The intake and the primary supply canals of the Taklai irrigation system that irrigates about 3,200 acres have been recently modernized under JICA support. However, its on-farm distribution systems remain in their pre-project states, and farmers are supposed to upgrade them to match the operational requirement of the main system. Unless the on-farm water distribution system is upgraded along with water management and agriculture extension activities, expected agricultural production from the overall Taklai irrigation system is not likely to be achieved.

Activities under the Taklai Integrated Crop and Water Management Project will be similar to those listed above for the sector wide approach of ICWMP. Besides these, the Taklai ICWMP will also focus on upgrading distribution canals to match the operational needs of the main system.

The Takali irrigation system is the largest in the country with modern infrastructure already in place. The project area is accessible to good market centers bordering the Assam state of India. In this context, the Taklai ICWMP will be developed as a model project, whose lessons can be easily disseminated to other irrigation projects located in southern Bhutan.

The estimated cost of Taklai ICWMP is USD2.4 million.

8.3.2 Institutional Strengthening and Capacity Building Project

Institutional strengthening and capacity building is a key component of irrigation development. Unless the existing irrigation institutions are properly strengthened and capacitated in line with the NIMP, the later cannot be implemented efficiently and effectively. This component of the project therefore aims at institutional strengthening and capacity building of the following organisations:

- DOA and its engineering units.
- Local government development organizations at district level.
- Irrigation WUAs formed or to be formed at project level.
- Private sector for irrigation related services.

Chapter 10 describes in more details the institutional development component of the NIMP.

The estimated cost of the institutional strengthening and capacity building component of NIMP is about USD 5.75 million.

8.4 Multi Criteria Analysis (MCA) for prioritization of the likely sub projects

Foregoing sections described the road map for developing irrigation in the country with several categories of structural and non-structural projects. Under each of these projects, numerous potential sub-projects are likely which will need to be prioritized for implementation using Multi-Criteria Analysis (MCA). Chapter 12 presents some of such subprojects, and Appendix A presents their long list.

Multi-criteria analysis (MCA) is a set of techniques for comparing alternative sub projects and producing a ranked list with the best projects at the top. It is a tool which can be used to score and rank proposed sub projects in a structured way. It involves a well-defined hierarchy of assessment criteria that are both quantitative and qualitative, and which are developed in consultation with stakeholders.

Advantages in using MCA in ranking potential subprojects under each of the four types of infrastructure projects described above are:

- Decision-making for sub project prioritization is transparent: reasons are clear and recorded.
- It enables the use of wide range of criteria for project selection.
- It provides a structured way of involving many stakeholders and follows the participatory approach allowing necessary discussions and argumentations while ranking the subprojects.
- Allows decision-makers to take ownership of the decision process.

8.4.1 Prioritization criteria

Five main criteria and several sub criteria have been developed in consultation with stakeholders. These are listed in Table 8.2 below.

Table 8.2: Main MCA criteria and their weight

SN	Main criteria	Weight	Sub criteria
1	Water availability	20	• What is the level of water availability for each cropping season? • Are there water conflicts in the area? • Does basin / sub basin plan exist in the sub project area?
2	Climate change and environment	20	• Is the sub project climate resilient? • What is the level of vulnerability to climate change? • Is there any negative environmental consequences?
3	Level of technical difficulties	20	• Is the project technically justifiable? • What is the main canal length with respect to the command area? • What is the command area?
4	Agricultural situation	20	• Is there a room for increasing the command area (for existing system)? • Is the subproject viable for cultivating high value crops? • Is the subproject viable for higher cropping intensity?
5	Social / socio-economic	20	• Is the subproject economically viable? • How many people (including women) benefit from the sub project? • How does the sub project fit with the regional development strategy (regional balance) • How supportive is the community of the subproject?

			• Is there a market easily accessible from the subproject area?

All main criteria are provided with equal weight. Weighting of sub criteria will be site specific, and thus these will have to be decided during project implementation in consultation with key stakeholders.

8.4.2 Applying MCA

Following steps are recommended in applying MCA for prioritizing sub-projects for implementation within the NIMP framework.

- Identify a set or long-list of subprojects to be prioritized.
- Review the main criteria and define sub-criteria in consultation with key stakeholders, mainly water users and irrigation system developers.
- Develop a scoring rule for each criterion: each sub-project will get a score against each criterion from 1 to 100. For example “water availability” could be a criterion with different situations or scenarios for sub-project scoring as shown in Table 8.3 below. Scoring rule should be developed in consultation with key stakeholders.

Table8.3: Scoring format for water availability for each subproject

	Water availability: Total score 20	
	Score	**Water availability**
Water availability good	100	Perennial source, adequate water resource
	75	Perennial source, moderate water resource
	50	Perennial source, but scarcity during summer
Water availability poor	25	Seasonal water source
	0	Not enough water even during the monsoon

- Develop a simple Excel template for applying MCA. Criteria may be given same or different weights for the evaluation of sub-projects in the MCA
- The scores of the subprojects against the different criteria and sub criteria considered are entered in the MCA Excel template to determine their rank. The best ranked sub projects are then selected for implementation.

9. Sustainability of operation and maintenance of irrigation systems

9.1 Background

Irrigation systems in Bhutan were traditionally developed, operated and maintained by communities through an array of social norms and local institutional arrangements. These systems were basic channels cut along the slopes and agricultural plots to provide water for subsistence farming only. Development, operation and maintenance were coordinated by village elders with labor contributions from the households in the community. It is only after the initiation of the development planning exercise in Bhutan that the building of new irrigation systems and the maintenance of existing ones were considered from the perspective of increasing agricultural productivity and marketing.

With economic planning, the arrangements for the development and periodic maintenance of irrigation systems have constantly evolved:

- **Government subsidies***:* Developments of new irrigation systems and bottleneck repair works for existing ones were primarily sponsored by the Royal Government of Bhutan with subsidies of up to 80% for funding for the procurement and transportation of materials. 20% of the total cost was required to be in-kind and/or though labor contributions from the beneficiary community.
- **Regular operation and maintenance (O&M)***:* Traditional norms and institutions continue to play an important role in regular operation and maintenance of irrigation schemes. Many communities rely on labor contributions from households for this. Water caretakers known as *Chhusups* are appointed to monitor and ensure that the water flows from the source to delivery points, and to enforce agreed water sharing arrangements. *Chhusups* are compensated in a variety of ways, including waiving of labor contribution and/or monetary compensation from each household.

With the adoption of the 2012 national irrigation policy, the scope for development and periodic repair of irrigation systems was broadened to include other areas than those irrigated for paddy. The policy also includes a provision for private sector engagement through outsourcing contracts, subject to availability of financial resources.

9.1.1 Planned intervention under NIMP and present agriculture practices in Bhutan

The planned interventions under the NIMP ultimately aim at enhancing agricultural productivity for food security, for which irrigation development is only a means. Sustainability of irrigation as an input to agriculture enhancement needs to be examined from the perspective of overall agricultural production system. For this, it is essential to have a good understanding of how agriculture is practiced in the country:

- **Characteristic of the agricultural land***:* Less than 8% of Bhutan's land is arable. Currently, 2.9% of the country's total area is cultivated by small and scattered rural communities in which households own multiple scattered plots of varying shapes, sizes and slopes.
- **Economic efficiency of agriculture for production of cereals***:* Small and scattered agricultural plots primarily located on hill slopes limit the possibilities for mechanization.

> Agricultural production is labor intensive and farming is not the preferred occupation for the young and the more educated Bhutanese. With rural-urban migration, agriculture in Bhutan is being left to the older and less educated generation. With limited farm labor, low mechanization possibilities, and damages caused by wildlife to harvests, agriculture in Bhutan is not economically efficient with high inputs required to secure low outputs. This explains why agriculture in Bhutan is largely for subsistence.

With low profitability and income for the local farmers, the prospect for them to be able to sustain the operation and maintenance of irrigation systems on their own appear rather distant. Dependence on government subsidies seems inevitable, at least in the short and medium terms.

Despite these challenges, the development of commercial agriculture in Bhutan is potentially viable as existing land resources (even irrigated) are underutilized. Considerable portion of land could be put under cultivation with adequate irrigation facilities, farm mechanization, working capital, market access support, and crop protection against wildlife. Some progress in this direction has already been made, especially as regard to the development of vegetable and horticultural crops. This trend could be further accelerated with adequate support services.

However, considering that subsistence farming is still prevalent, it would be unrealistic to immediately expect farming communities to sustain the operation and maintenance of newly developed irrigation systems until agriculture has become more profitable and WUAs have been sustainably established. A long term step-by-step approach based on a gradual reduction of government subsidies must be adopted.

9.2 Proposed maintenance approach

The foregoing Chapter outlined the road map for the development of irrigation in Bhutan. Newly developed (or modernized) irrigation systems need to be properly maintained and managed, as otherwise they may enter into a vicious cycle of constant rehabilitation – deterioration–rehabilitation, making the investments not economically viable or sustainable.

With the planned improvement of the existing irrigation systems, much of the infrastructures that are of temporary nature will be replaced by a wide variety of more permanent structures that may be built using foreign materials like reinforced concrete, steels, pipes, and others. Different types of water lifting devices[58] may also be installed for the diversification of water sources for irrigation. These new infrastructures will require additional resources (including capital) and measures to be put in place to ensure sustainability.

In this context, the following interventions are proposed

9.2.1 Institutional mechanisms for O&M of irrigation systems

While the profitability of agriculture may determine the extent to which communities can support the O&M for irrigation systems, the way water users are organized for collective action is equally important. In this regard, the mechanisms outlined below are proposed.

9.2.1.1 Water User Association as the conduit for government assistance

Considering the traditional practices of maintaining existing irrigation systems through community participation, and also considering the smaller size (in terms of area coverage) of the planned irrigation development, the irrigation systems to be developed under the NIMP will be handed over to legally registered WUAs for their O&M[59]. To be successful, WUAs will have to be entrusted with the legal

[58] These may be driven by electricity, gasoline, solar energy and water power

[59] It is to be noted that even the newly developed Taklai Irrigation System irrigating 3200 acre of land has been handed over to WUA for operation and maintenance.

authority necessary for managing the irrigation systems that would include the collection of irrigation fees from the water users.

However, it is well recognized that simply handing over irrigation systems to WUAs will not alone make them capable to sustainably managing the systems. WUAs need to be strengthened technically, financially as well as in terms of governance through intensive institutional development support and capacity building. This requires substantial time and resources. Recognizing this, it is proposed that until the WUAs become technically and financially sustainable, they should be supported by the government for O&M, especially for the more technically demanding irrigation facilities.

9.2.1.2 Irrigation fees to be instituted by WUAs

In an effort to prepare WUAs to take responsibility for O&M, it should be made mandatory for them to established and manage an O&M fund made of irrigation fees payable on a regular basis by the water users. WUAs may determine the amount of the fund and modalities for fee collection but it would be expected that the accumulated fund should cover a sufficient portion of O&M costs. Besides this, labor intensive maintenance activities should also be continued through the existing community based labor mobilization practices.

9.2.1.3 Capacity building of WUAs by DOA

The DOA has a critical role in ensuring consistent and efficient operation and maintenance by WUA of newly developed irrigation systems. Periodical trainings and technical backstopping of WUAs is proposed to enhance their ability to operate and maintain the irrigation schemes sustainably. The operation, maintenance and research unit under the Irrigation and Water Management Section (IWMS) shall be made responsible to plan and coordinate the trainings and technical back stopping activities required to this end.

9.2.2 Organizational setup

An irrigation maintenance unit with adequate staffing shall be established under the proposed Irrigation and Water Management Section (IWMS) of the Engineering Division to provide technical assistance to WUAs for maintaining irrigation systems.

9.2.3 Government subsidy for operation and maintenance of irrigation systems

Until such time when agriculture production becomes more profitable, it is expected that WUAs will require external support for the operation and maintenance of the newly developed irrigation systems, especially for the more technically demanding facilities. For this, two avenues of government subsidies are proposed:

9.2.3.1 System level O&M funds

While it is desirable that WUAs increasingly assume responsibilities for O&M, there are communities that because of the location where they are settled, the limited number of water users and/or economic backwardness, cannot afford to fully maintain their irrigation systems on their own, and therefore require government support. O&M support for such communities may be provided through the existing government budgeting systems

9.2.3.2 Central Irrigation Maintenance Fund (CIMF)

As noted above, WUAs are expected to create an O&M fund through the collection of irrigation fees from water users. However, this process may take time and until WUAs become financially capable, they may need to be supported.

It is therefore proposed to establish a self-sustaining Central Irrigation Maintenance Fund (CIMF) to be managed by the Bhutan Development Bank Limited (BDBL).When needed, WUA should borrow collateral free loans from this fund at low interest rates. Only legally registered and operational WUAs would be eligible for such soft loans. Guidelines for managing the Central Irrigation Maintenance Fund (CIMF) and necessary regulatory framework will need to be developed during the initial phase of NIMP implementation.

The proposed operation, maintenance and research unit under the IWMS of the DOA's Engineering Division would, in addition to monitoring O&M of the irrigation schemes, be responsible to verifying the genuineness of the WUAs' needs for loan.

9.2.4 Linkages between irrigation and agriculture

As noted above, additional capital resources for irrigation systems maintenance will have to come from the benefits of improved agriculture productivity. In respect of this, the NIMP proposes to implement the Integrated Crop and Water Management Project (ICWMP) that aims to maximize agricultural production from the developed irrigation systems.

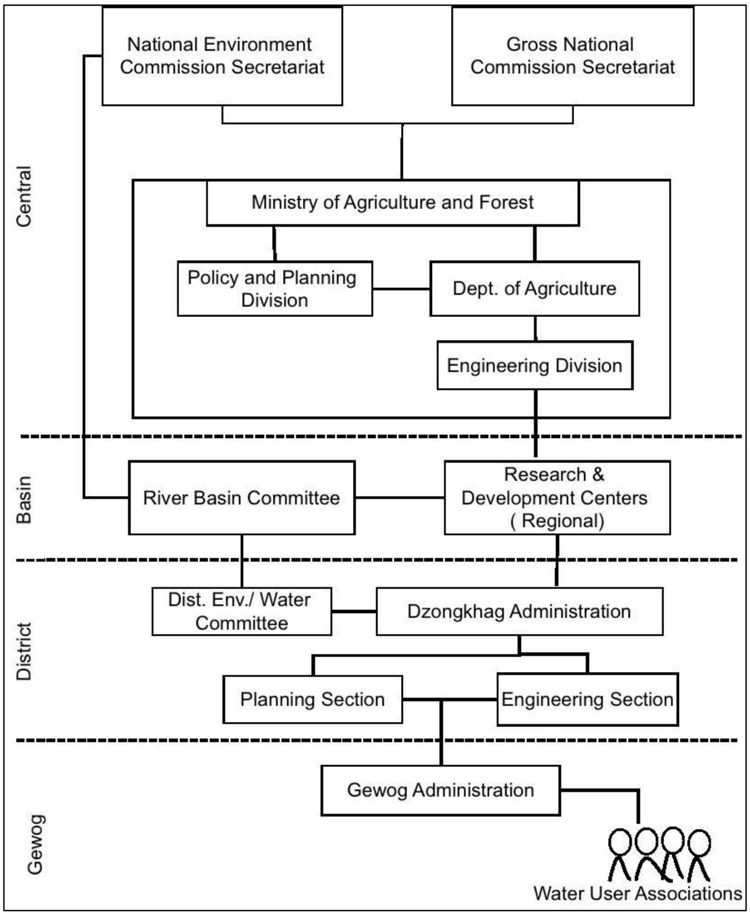
10. Institutional strengthening and capacity building

10.1 Background

This chapter deals with the institutional and capacity development needs for effective implementation of the National Irrigation Master Plan (NIMP). For this, it is important to first understand the foundations and considerations upon which this NIMP is based. This plan is an important component of the Royal Government's endeavours to foster water security as defined by the National Integrated Water Resource Management Plan (NIWRMP) and Bhutan Water Security Index (TA 8623 R1, 2016).

In aiming to achieve water security in the agriculture sector, this plan targets bringing 91,000 acres of agricultural land under irrigation to meet 75% self-sufficiency for paddy (rice), and 80% self-sufficiency for all cereals by 2032. A number of projects are proposed to bring more agricultural land under irrigation. Translating this plan into outcomes and outputs will entail adequate finance, human resources, and effective and efficient institutional mechanisms. Recognizing this, section below first provides an overview of the institutional linkages and key players (Figure 10.1) in the context of NIMP as an important component of the NIWRMP. Based on this assessment, institutional and capacity development interventions are proposed for implementing the NIMP.

Figure 10.1: Overview of Institutional linkages in irrigation planning and implementation



10.2 Institutional linkages and key players in irrigation management

The key players in the implementation of NIMP encompass all those agencies at the central, district and local levels that are directly or indirectly involved in identification, planning, implementation and management of irrigation projects. Based on the Figure 10.1, the key players, their roles and level of engagement is summarized below in Table 10.1

Table 10.1 : Key players, their roles and levels of engagement

Level	Key players and their roles
Central	**Gross National Happiness Commission Secretariat (GNHCS**): Toward the goal of Water Security for Bhutan, adopt Bhutan Water Security Index. Ensure that sectoral plan KRAs and KPIs are aligned with relevant BWSI dimensions and indicators. For DOA's Engineering Division, ensure KRAs and KPIs are aligned with Agricultural water security under economic water security dimension.
	National Environment Commission Secretariat (NECS): As the apex body for water resources, the NECS is responsible for coordinating water resource management in the country. The Water Resource Coordination Division, as the custodian of NIWRMP shall liaise closely with the GNHCS in ensuring that the water related sectorial KRA and KPIs are in line with the NIWRMP and the BWS indicators. In monitoring the overall progress on agricultural water security, the WRCD will ensure the DOA inputs the progress information in the online BWSI information system on an annual basis.
	Ministry of Agriculture and Forest: As the primary agency responsible for promotion of agriculture, the MOAF has the overriding responsibility of ensuring components of NIMP are integrated into the Five Year Plans on a priority basis. The Policy and Planning Division, in particular is responsible for working in close collaboration with the Department of Agriculture to ensure the outcomes of the irrigation projects are set in line with the relevant agricultural water security indicators. **The Engineering Division of DOA** has the responsibility of holistically coordinating implementation of the plans. For this, the Division will in consultation with the district administration arrive at the category and list of irrigation projects to be implemented by the central agencies and by the district administration. The projects to be implemented by the central agencies may then be delegated to the RDCs for implementation. This entails conducting feasibility study, preparing detailed project reports and design, contract documentation, tendering and management, supervision, operation and maintenance, and periodical reporting.
Basin	**River Basin Committees (RBC)**: The RBC is the basin level coordinating entity that the government will establish with the preparation of River Basin Management Plans (RBMPs) for each basin. Information on irrigation and irrigation systems from the district levels will be gathered and maintained. The RBC will monitor irrigation water demand against the available water in the basin and accordingly advice the NECS on allocation of water for various purposes including irrigation needs in accordance with the priorities set by law. With information support of the district environmental committee/ district water committee, the RBC Secretariat shall maintain up to date records of water allocation and balance.

	Research and Development Centers (RDCs): It is proposed that the jurisdiction of RDCs be aligned to the boundary of river basins. Accordingly, the proposed role of RDCs include: i. Providing technical backstopping to the concerned district engineering sections of the basin in a irrigation planning and design based on water balance and local conditions b secure water allocation permits from the concerned RBC of the basin c contract preparation, award, and supervision d collaborate and coordinate with district engineering section for O&M and periodical inspection of the irrigation systems ii. Regularly collect and maintain up to date information on all indicators of the agriculture water security for districts and Gewogs in the designated basins including information on irrigation systems, sources, area irrigated, agricultural crops and annual outputs. iii. Prepare and submit annually, the updated information to the Engineering Division, which in turn will input the updated data in the BWSI system. Such information could be shared with the districts and RBCs of the concerned basin.
District	**Dzongkhag Tshogdu:** The Dzongkhag Tshogdu in deliberating and finalizing priorities for the district. Irrigation priorities will certainly be covered. **District Environment Committee/ District Water Committee:** The district environment committee is also the designated district water committee. It is the authority with the power to grant environmental clearance for projects of certain nature and size. In terms of irrigation project, it is proposed that the committee will, on the basis of water balance information, issue clearances for district level small scale irrigation projects. It is proposed that the district environmental officer, as the member secretary to the committee, will maintain up to date account of water allocation and balance, which will serve as a basis for the committee's decision making. Such information shall be made available to the RBC for water accounting at the basin level. **District Administration**: The Dzongkhag Administration is the administrative channel for facilitation and coordination of development planning, implementation, monitoring and reporting. With respect to the implementation of NIMP, the Dzongkhag planning section will coordinate with Engineering Division of DOA in arriving at the list of projects to be implemented by the district administration. Accordingly, it will ensure that the projects are integrated in the five year plans and into annual plans. The **Dzongkhag engineering section** will provide the technical services in planning, design, and implementation of those irrigation projects identified for implementation by the district. It will also provide support to WUA for O&M of developed irrigation systems
Gewog level	**Gewog Administration**: This is the level at which beneficiaries are based and therefore all irrigation projects and programmes are implemented. It is also the proposed official channel for filing registration for water user associations (WUAs). The Gewog administration in turn will recommend the applications to the District environment/ water committee for final approval including the allocation of water and associated use rights.
	Water User Associations: Based on the Water Act and its regulations, water is a state property and no individual or entity has the rights to exploit the resource as they wish. Water users may organize themselves into a group or association to legally

	obtain rights for one or multiple use of the resource e.g. for drinking, irrigation, industry etc.

10.3 Proposed capacity building for irrigation planning and management

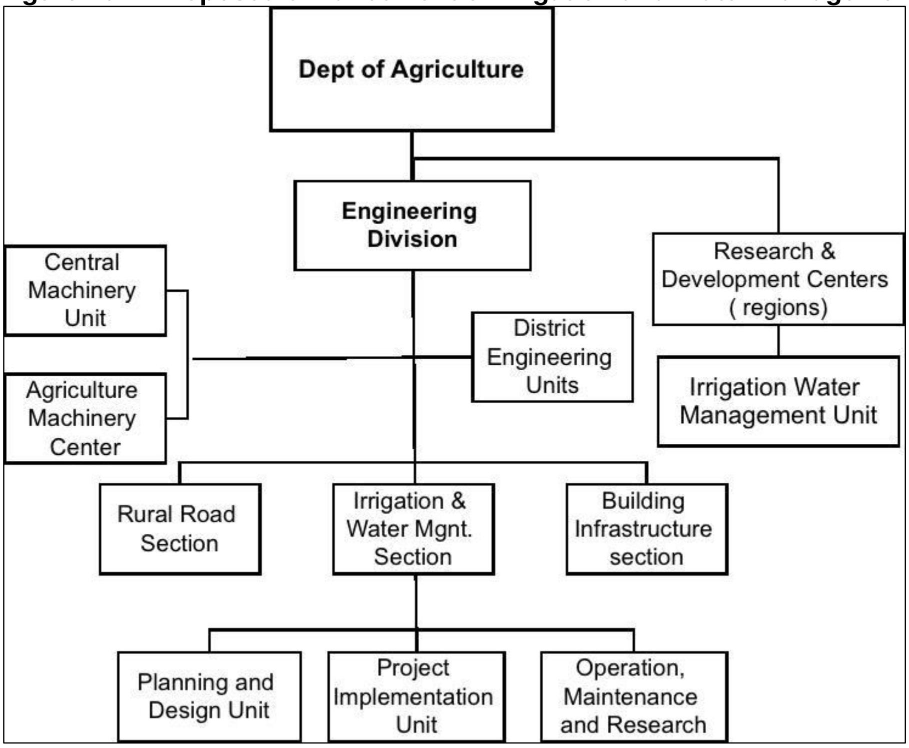
The Ministry of Agriculture and Forest (MoAF), through the Department of Agriculture and specifically its Engineering Division, is the competent authority on national irrigation development in Bhutan. The Engineering Division is responsible for planning, implementing and O&M of the country's irrigation systems in line with the 2014 Water Regulation and the National Integrated Water Resource Management Plan (TA 8623 R1, 2016).

For the Department of Agriculture's institutional development component of the NIMP, it is proposed to establish and strengthen an Irrigation and Water Management Section (IWMS) under the Engineering Division, as outlined below.

10.3.1 Establish and strengthen Irrigation and Water Management Section (IWMS)

Implementation of the NIMP may be seen in terms of the steps applied in project cycle management namely identifying and conceptualizing, conducting feasibility studies, preparation of detailed project report and designs, contract management, implementation supervision, project handing over, O&M, and monitoring and information management. It is proposed that the activities in each step are carried out by three additional units to be placed under the Irrigation and Water Management section at centre and Irrigation Water Management unit at region (Figure 10.2).

Figure 10.2: Proposed enhancement of Irrigation and Water Management Section



The functions of the three proposed units are described below:

10.3.1.1 Planning and design unit:

The primary function of this unit is to coordinate identification, design, and development of irrigation projects in the country. This entails:

Identifying and conceptualizing: The Identification and conceptualization of projects is ideally to be carried out every five years. While this is an on-going process, the concepts are put together and integrated in the five year plans. A number of project concepts have been developed under the NIMP.

Conducting feasibility studies: The project concepts are further assessed in term of feasibility for implementation. This will entail site visits and carrying out the necessary social, economic and technical feasibility. Accordingly, the non-feasible ones are dropped and feasible ones put through for further preparation of detailed project report and designs.

Preparation of detailed project reports and designs: In this step, detailed project reports and implementation plans including detailed designs, drawings of proposed infrastructure and cost estimates are prepared.

It is possible that there may not be adequate qualified in-house engineers to undertake such tasks. Under such circumstances, the project development work could be outsourced. To guide design and development of irrigation projects, the unit should develop and update guidelines and technical manuals.

Synergy with NIWRM plan and RBM plans: Check that the developments plan for irrigated agriculture is coordinated with water related plans including the NIWRMP, River Basin Management Plans, hydropower development plans and other water-dependent programs. For this, the unit is also responsible for securing water allocation permits from the competent authorities such as the District Environment/ Water Committee and or River Basin Committees depending on the size of the project.

10.3.1.2 Project implementation unit:

This unit will focus on coordinating implementation of irrigation development projects through a) contract preparation and management; b) quality control and site supervision; and c) post project hand over to water users. Specific tasks include:

Contract documentation, award and management: Where the implementation needs of the project is beyond the capacity of the Engineering Division and its affiliates, there is the option of outsourcing the implementation to private sector. In such a case, the contract documents should be prepared, floated, evaluated, and awarded in accordance with the procurement rules of the government/ funding agency. Once the contract is awarded, the extent to which the contract terms are being fulfilled must be monitored.

Implementation and supervision: The work of the contractor must be constantly monitored for quality and compliance with specifications. The unit must be entrusted with the responsibility of designating or mobilizing engineers for supervision of specific project. This may include delegating the function to respective RDCs for supervision of the projects in the basin. Alternatively, in the event of lack of expertise and manpower, supervision work could also be outsourced.

Project handing over: Once the project implementation is completed, the irrigation structures and facilities are then handed over to the water users that from hence forth would be in the form of water user associations (WUAs). Unless assessed as requiring government assistance, the WUAs are expected to sustain operation and maintenance of the facilities.

10.3.1.3 Operation and maintenance, and research unit

This unit will focus on two aspects: (a) operation and maintenance of irrigation systems, and (b) research and information management. Specific tasks include:

Operation and maintenance: With the NIMP intervention, developed irrigation systems may be equipped with modern infrastructures that may require specific knowledge and resources for their operation and maintenance. This unit will provide services to WUAs in meeting such O&M needs.

Research and information management: Besides providing services for O&M of developed irrigation systems, this unit will collect and update information on functionality, irrigation command area, agricultural production, cropping intensities, irrigation fees, etc. It will also collect and update information on the indicators pertaining to agricultural water security.

As an on-going activity, this unit will also be responsible for analyzing and reporting the performance of irrigation systems. While doing so, the unit will maintain close coordination with the concerned water sector stakeholders like WUA, RBC, NECS, and others.

10.3.2 Staff development of the Engineering Division

As noted above, the Engineering Division of DOA is presently staffed with 24 engineers, of which 9 are posted in three Regional Development Centers (RDCs) which provide support to district administrations (3 staff are posted in RDC Bajo, 2 in Bhur, and 4 in Wengkar). The remaining 15 engineers are distributed across three sections: (a) rural road, (b) irrigation, and (c) other infrastructure. It is therefore clear that the staff capacity of the Engineering Division is inadequate to take up the implementation of the NIMP.

Recognizing this, it is proposed to conduct a detailed institutional assessment of the DOA's Engineering Division soon after the approval of the NIMP. This will assess the need for staff development at both the center and RDCs for NIMP implementation[60].

However, it may not be possible to add a large number of staff to the IWMS in view of the national policy of streamlining the government bureaucracy by reducing the number of personnel[61] . Thus, in addition to establishing the IWMS with some new staff, it is proposed to mobilize the private sector for outsourcing the detailed planning and implementation of irrigation projects.

10.3.3 Intervention within the Irrigation and Water Management Section (IWMS)

The IWMS to be established under the DOA's Engineering Division will need to be strengthened to be able to function efficiently. The following interventions / activities are proposed to this end.

- Develop a detailed project implementation procedure guidelines starting from project identification to operation and maintenance. This guideline will also define roles and responsibilities of WUA, IWMS, and district / Gewog administration, RBC, District water committee etc.
- Strengthen institutional linkages and key players in irrigation planning and implementation
- Institutionalize design guideline and manual developed by this TA (TA 8623 R3, 2015) in planning and designing irrigation system.
- Acquire computer-assisted irrigation system design tools.
- Update the existing national irrigation information system.
- Setup a water availability database (including climate change projections) to support irrigation planning, particularly water allocation in times of seasonal water scarcity.
- Setup an irrigation sector M&E system.

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60 Preliminary assessment suggests that it may be appropriate to strengthene each unit of IWMS at centre with 3 professional staffs and each Irrigation and Water Management Unit at region with 2 staffs. Total additional professionals staffs will then be 9 at center and 6 at regains.

61 The Royal Civil Service Commission has always been aiming at a small, compact, and efficient civil service.It has generally been the case that requestsfor additional staff are not fully entertained.

- Conduct trainings for: (a) staff of the IWMS of Engineering Division, (b) Rural development engineers under the district administrations (c) engineers from private sector, and (d) WUAs.

The ADB TA report on "Strengthening of the Department of Agriculture and Water Users Association (TA 8623 R2, 2016) provides details on computer-assisted irrigation design tools to be acquired, updating national irrigation information system, setting up water availability database and M&E systems, and proposed trainings to WUAs and DOA.

10.4 Strengthening water users associations

As noted above, existing irrigation systems in Bhutan are generally managed by locally recognized traditional community organizations. The irrigation systems that will be developed (or improved) under the NIMP are to be handed over for operation and maintenance to their respective water users. Current policies and regulatory framework require that irrigation water users form legally recognized WUAs.

The WUA to be formed for each irrigation system will need to be registered with DOA as a legal entity, and strengthened for O&M. Following interventions are proposed to this end:

- Update the existing DOA manual for forming and training WUAs. The existing manual was prepared in 2013 with support from SNV Netherlands Development Organization (SNV, 2013).
- Institutionalize the collection of irrigation fees by WUAs for sustainable operation and maintenance of the developed irrigation systems.
- Update existing regulatory framework for empowering WUA to legally manage the irrigation systems, especially as regard to collecting irrigation fees from the water users.
- Provide adequate capacity building training to WUA.
- Provide technical support to WUA for sustainable O&M of developed irrigation systems
- Monitor the performance of WUA.

TA 8623 R2 (2016) provides further guidelines for strengthening WUAs for irrigation management

11. Likely irrigation technologies following international best practices

11.1 Irrigation technology

Irrigation technologies are meant to match the physical and economic conditions of the areas in which they are meant to be used. The physical settings are determined by climate, soil, topography, water availability, type of water source, method of irrigation and crops to be planted. The economic factors may include cost of investment, cropping patterns, market availability, irrigation experience, and local land and/or labor cost structures. The choice of technology is hence site specific. In addition, water use technologies for irrigation are considered in a sequence from water acquisition or water source to water application on the farmer's field.

11.1.1 Selection of irrigation technology

Prior to designing an irrigation system, it is essential to decide on the irrigation technology to be adopted in the field. Technology here is conceptualized as an artefact (or physical system) capable of delivering irrigation water to meet the desired objective. To choose the most appropriate irrigation technology for a particular setting one must know their advantages and disadvantages under various circumstances. The suitability of a particular irrigation technology also depends on factors like natural conditions, type of crops, irrigation methods, irrigation experience, required labor inputs, and costs and benefits

As noted above, the NIMP aims to improve existing irrigation systems as well as develop new schemes for expanding irrigation in Bhutan. This will mainly be done through the development of conventional surface irrigation and water harvesting and micro irrigation (pressurized piped systems), which require three categories of technologies, as follows:

- Water acquisition technology
- Water conveying technology, and
- Water distribution and use technology

The paragraphs below describe likely irrigation technologies that can be deployed for both the surface and pressurized irrigation systems.

11.2 Surface irrigation

Improvement of existing irrigation systems and development of new systems under the New Hill Irrigation Development Project and Wet Subtropical Irrigation Development Project involve surface irrigation. Related technologies are presented below.

11.2.1 Water acquisition technology for surface irrigation

11.2.1.1 Gravity flow water acquisition

In the hills and mountains the sources of water for irrigation are rivers, streams and springs. The water-acquisition structures, whether they are permanent or temporary, are constructed to take off water from the water sources. The selection of the type of intake structures depends mainly of the objectives of the project, specific site conditions, and requirements of the irrigation system. The general criteria that affect the selection of the intake structures are the effectiveness in acquiring water for irrigation, effectiveness in excluding sediment entry into the canal, ease and relative cost of structure, effect of floods in terms of damage risk, and flow control to the canal system.

Based on how water is diverted from the source, intake structures are grouped into three types: 1) side intake with and without dam across the river, 2) bottom intake, and 3) underground dam.

Side intake

The side intake with damming is the most common type of structure and consists of a weir across the river, a head regulator, a under-sluice and a fish pass in case of large rivers. Side intakes with damming are constructed where a significant amount of water is to be diverted from the source whereas intake without damming is suitable only for the diversion of the small amount of water from the river (Figure 11.1).

Figure 11.1: Side intakes with and without damming the river

Side intake with damming the river	Side intake without damming the river
	

In addition, intakes without damming are more economical for small scale irrigation systems in the hills and mountains. The amount of water to take off from the river is dependent on the water level in the river. In case of low flows, the water level has to be raised by building temporary structures.

There are cases where side intakes (with damming and without damming) are not feasible due to various reasons and other more appropriate gravity water acquisition structures are to be considered. Some of these structures are briefly described hereunder.

Water diversion in foothills: Bottom rack intake

Bottom rack intake is also known as Tyrolean intake or Trench intake. It is placed in the river bed to draw off water through the trench and convey the flow to the main canal (Figure 11.2). The trench is covered with the screen bars or racks on the top to prevent large sediment entering into the trench. The trench length on the weir across the river depends upon the requirement of the flow and openings of the bars. This type of intake is mostly suitable in the region where the rivers have low sediment concentration. The main components of a bottom rack intake are a weir across the river, bottom trench, trash bars over the trench, feeder canal up to the settling basin and settling basin to flush the sediment.

Figure 11.2: Bottom Rack intake of Taklai Irrigation System

Bottom intake	Steel bars over the trench

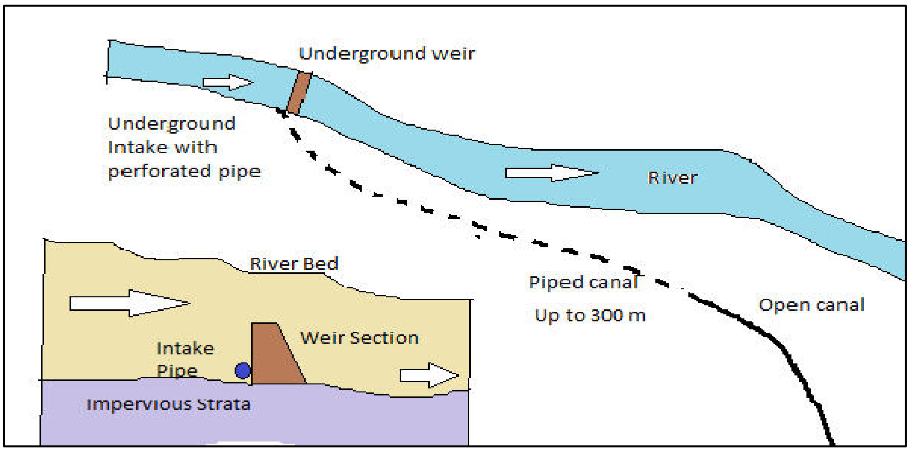
Source: ADB TA 8623 site visit

Underground dam

An underground dam obstructs the flow of groundwater and stores the water below the surface. The stored water underneath the surface can either be extracted above the ground or diverted through gravity downstream of the dam area. This technology is the underground diversion built below the ground level to uplift or divert the available flow of the river underneath the bed.

The underground dam technology has been used since ancient times. An impermeable dam built across a surface aquifer, such as bed of a sand-filled river and based on the top of an impermeable layer. The crest of the dam shall be at least 1 m below the ground surface, which prevents the land becoming water logged. The body of the dam must be sufficiently massive to withstand the pressure and properly constructed for stability and tightness. The height of the underground dam shall be between 1 m to 4 m depending upon the requirement and topography. Water is generally diverted by constructing an intake with perforated pipes like the side intake (Figure 11.3). The stored water can also be drained through the reservoir bottom along the upstream side of the dam, and connecting the drain to a well or to gravity supply pipe through the dam wall. The dams may be built with concrete, stone masonry, gabion with clay core, or stone fill concrete.

Figure 11.3: Schematic layout of underground dam



The application of underground dam may be feasible in southern foothill areas of Bhutan. The characteristics of small rivers in this area are steep slope, large variation of discharge even during the monsoon months, wide river channel, flash floods, rising of river bed, and comparatively small water catchments. These rivers are almost dry during the non-monsoon months (Figure 11.4). Construction of surface intake structures in these rivers is full of problems related to the siltation and sedimentation, and lack of water at the surface. To overcome these natural geo-morphological problems in the foothill areas construction of underground dam might be the proper solution. An assessment carried out in southern districts of Bhutan reveals the possibility of constructing underground dam in Sarpang districts to solve the issues of irrigation in dry season (JICA, 2012). This technology is also being used in arid regions of Africa for drinking water supply purposes. Similar technology also exists in Chautara Irrigation System[62] in Chitawan, Nepal. In addition, this technology is being used for irrigation in semi-arid areas of Brazil in Mutuca valley (Ellis, J. 2006).

Figure 11.4: Dry Bed Rivers at southern foothills of Bhutan

11.2.1.2 Water lifting technologies for water acquisition

Water lifting from nearby source is one of the ancient technologies for irrigation where water cannot be acquired with the gravitational means. Several water lifting devices have evolved in arid zones staring from Persian wheel to modern pumps. Requirement of the energy for lifting the water is the major deciding parameter on the selection of lift system. Manual power, oxen power, fossil fuel engines, solar power, hydraulic energy and electric motors are the examples of energy suppliers for lifting the water. Some of the water lifting technologies which may be suitable for Bhutan are briefly described hereunder.

Hydraulic ram

Hydraulic Ram (hydram) is a pump to lift water from the flowing water source by utilizing water power. The pump does not require any fuel or electricity and operates with water hammer effect of flowing water. The special feature of hydraulic ram is that the water hammer effect is caused by the water itself. Hydraulic ram pumps are being used to lift small discharge to a significantly higher elevation through a low head high discharge water power input. The hydram concept was first developed in France in 1796 (Shrestha et al, 2012).

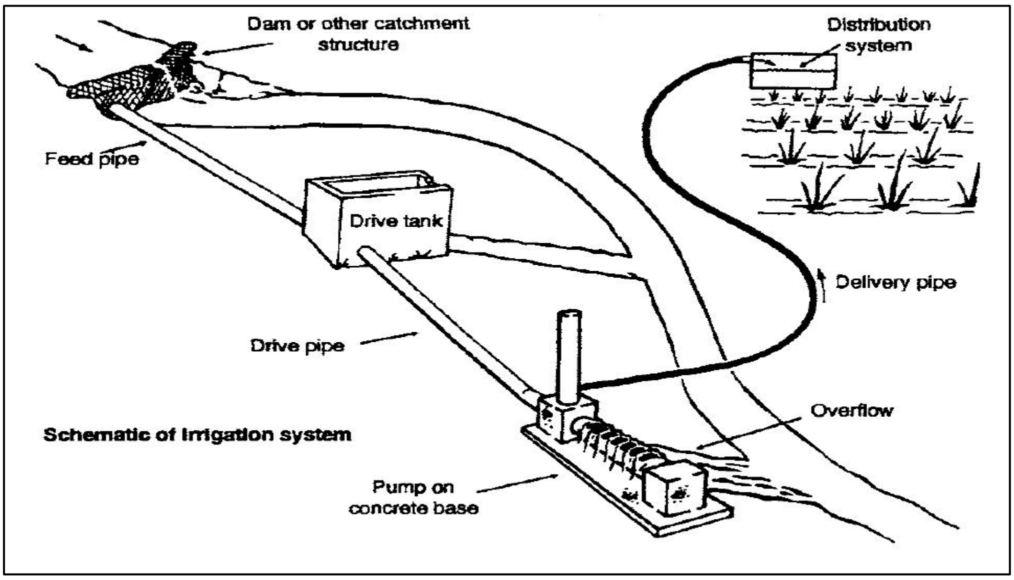
A hydraulic ram technology is an automatic pumping device which uses large flow of falling water through a small head, to lift a small flow of water through a higher head. This technology is mechanically simple and sustainable. In addition, this technology provides reliability, low operating costs, minimal maintenance, and long life. Hydraulic ram pump system consists of the following components:

i. Water source or stream or river

62 Chautara irrigation system irrigates to about 70 ha of land in monsoon season and 30 ha of land in dry season

ii. Feeder pipe
iii. Drive tank
iv. Drive pipe
v. Pump basement with hydram
vii. Delivery pipe and distribution system

Figure 11.5: Components of Hydram Pump



The water is diverted from the source stream or river to the drive tank through a feeder pipe (Figure 11.5). The drive tank allows a continuous flow to the drive pipe and the pump. The drive pipe is strong enough to support the water hammer effect which is running continuously. The drive pipe is designed to deliver water as fast as possible to the pump. Hence, the alignment of the drive pipe should be straight. The Hydram is the most important structural component of the system. It is attached with pump basement. The Hydraulic Ram Pumps have many designs all over the world. The main components of the pumps are pump body, impulse valve, delivery valve, air vessel, and snifter valve. The pump body should be sound enough to resist water hammer effect. The configuration of the pump depends upon the manufacturer's design. The Hydram has to absorb the shocks of the water hammer effect. The pump basement has to be carefully designed because it is subject to the fatigue of the water hammer effect. The delivery pipe supplies the water from the pump to the outlet tank and distribution system. The ratio of driving flow to the delivery flow is inversely related to the ratio of driving head to pumping head.

The hydram technology in the hilly areas of Bhutan is only suitable for small scale irrigation. One system can deliver 1000 to 100,000 liters of water per day to a reservoir up to 200 m above the source. It has a low installation cost, little maintenance and has no operating costs. Since it only uses waterpower to pump water up, it mitigates the carbon emission and high cost associated with conventional diesel powered pumps.

The mode of operation of Hydram pump depends on the use of the water hammer phenomenon and overall efficiency is good under favourable circumstances. As hydram pump has only two moving parts (waste valve and delivery valve), it requires little maintenance.

Barsha pump

Barsha pump is a new innovative water lifting mechanism for small holder farmers to irrigate their field using no electricity or fuel. The pump is based on the ancient principles of Persian Wheel lift and is environment friendly, easy to install, sustainable and low cost (Figure 11.6).

Barsha pump requires flowing water to operate either from the river or from the canal. The main operational requirements are: i) minimum velocity of flowing water, ii) width of the channel or river, and iii) depth of water in the channel or river

Figure 11.6: Typical Barsha Pump

The discharging capacity of the pump depends upon the velocity of water in the channel or river. Higher the velocity faster the rotation of the wheel of the pump and hence delivers higher amount of water. The boundary conditions of the Barsha Pump are presented in Table 11.1.

Table 11.1: Boundary conditions of Barsha Pump

S.N	Parameters	Minimum boundary conditions	Current pilot operation	Nominal operation
1	Velocity of water (m/s)	0.50	0.80	1.20
2	Flow rate or discharge (l/s)	150	300	0.40
3	Width of the channel (m)	0.60	0.80	0.80
4	Depth of the channel (m)	0.25	0.30	0.35

Source: (aQysta, 2015); www.aQysta.com

The advantages of Barsha pump is its low investment and maintenance costs. This pump is suitable for irrigating small plots of land along the banks of river or channel. The main constraints of Barsha pump are the requirements of flowing water and the fact that it is only feasible for low height lifts.

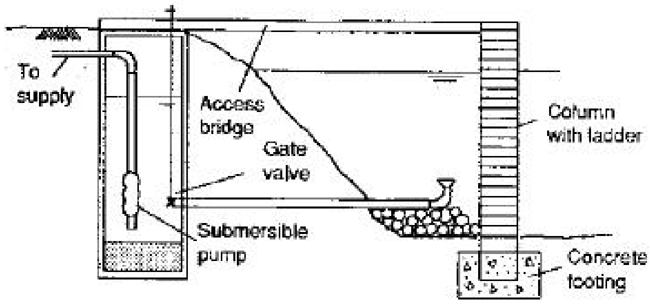
Sump well intake and pumps

Sump well or Jack well is the intake located at the stream bed to make water available for lifting. The wells are properly lined with cement concrete with provision of perforations or windows for receiving water through direct percolation. The height of the wells should be high enough to protect them from high flood water. Sump wells are also constructed on the stable river banks adjacent to the river bed. In this case the water from the river can be supplied either by the open channel conduit or through perforated pipes. Pumps are installed close to these wells and are well protected from flood water (Figure 11.7).

Figure 11.7: Typical sump well intakes

Sump well intake at Punakha

Diagram of typical sump intake



Source: ADB TA 8623 site visit

Floating intake and pump

Floating intakes abstract water from nearby water surfaces of the river to the higher level areas through a pump. The inlet pipe of a suction pump is kept just under the water level to a floating pontoon that is tied with the banks. The pump is located on the banks of the river. The pontoon can be made locally using empty oil drums or plastic containers framed wooden and steel works. In the situation where the construction of pump house is not feasible on the banks of the river, the pumps may be installed on the floating platform. In this case the platform should be sound enough to withstand the load of pumps and other accessories. Alternatively pumps can move up and down in sloping railing in order to reduce the length of the suction pipe. This floating intake and moving pump technology has been installed in Bajo, Wangdue and being operated successfully to irrigate pilot agriculture farm (Figure 11.8).

Figure 11.8: Floating intake and pumps in Bajo, Wangdue

Pumps and sloping rails

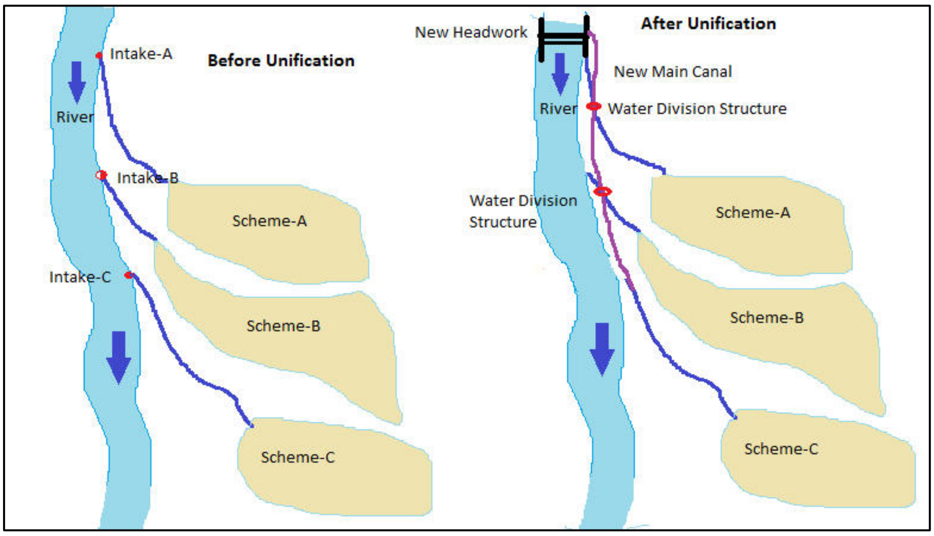
Floating drums

Source: ADB TA 8623 site visit

11.2.1.3 Unification of intakes

Unification of intakes is the combining of small schemes into a new larger scheme with the construction of permanent water diversion intakes or head works (Figure 11.9). A new feeder canal joins all unified canals with appropriate structures to distribute water proportionately. Many existing irrigation systems are aligned parallel from the same source river and have no water diversion structures across the river. Water diversion onto these systems is cumbersome especially during the monsoon months. With the construction of a new diversion intake at a suitable location near the first intake, water supply situation can be improved in terms of its reliability as well as sustainability. The unification technology is both technically feasible and economically justifiable for efficiency improvement of existing systems. However, social aspects of water allocation and distribution need to be considered prior to plan and design the unification of intakes. One of the main constraints is being able to reach agreement within the community to operate and manage jointly the system. Farmers of both upstream and downstream systems shall agree to form a joint WUA responsible for its operation and maintenance.

Figure 11.9: Schematic diagram of unification of Intakes

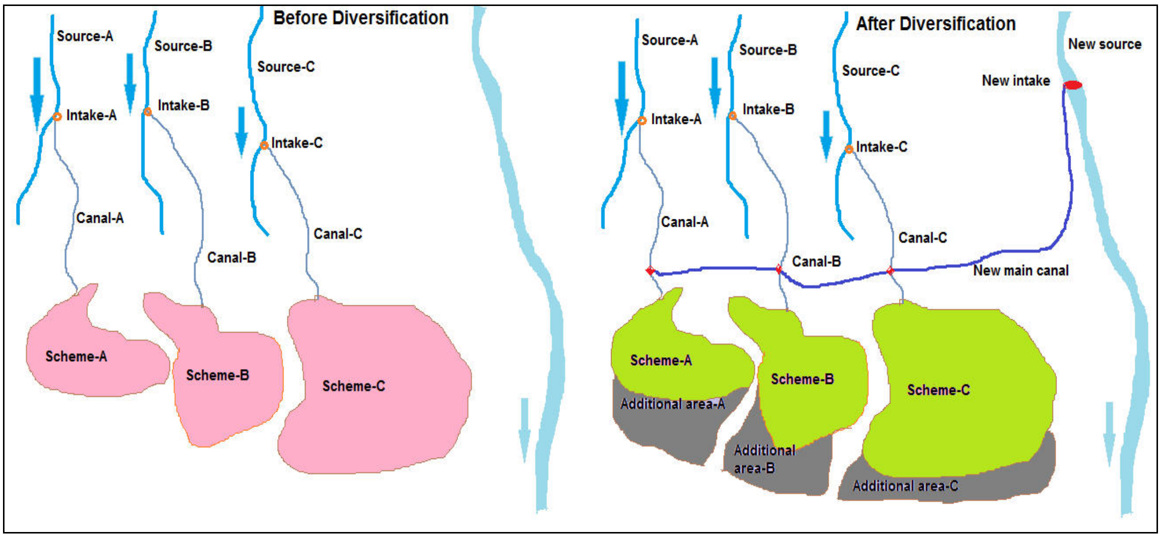


11.2.1.4 Diversification of water sources

The objective of diversification of water sources is to augment the amount of water supply for irrigation by taping more reliable sources than the existing seasonal sources. Water for irrigation is scarce during dry season as small streams and rivulets have no or little water at that time. The water sources are either seasonal or the available water is already been tapped for drinking water upstream of the irrigation intake. The diversification of water sources can help provide relatively reliable water supply for irrigation and increase cropping intensity and crop production.

The approach of water source diversification relates to making water supply more reliable for irrigation. It also includes unification of existing small irrigation systems to make a new large irrigation system (Figure 11.10). Besides improving cropping intensity in the area already under irrigation, it also extends the irrigation command area with the availability of additional water for irrigation.

Figure 11.10: Schematic diagram of diversification of water source



11.2.2 Water conveyance technologies

Irrigation water is conveyed from the source to the command area through a network of open channels and/or pipelines. Open channels may be lined or unlined and pipe lines partially open to atmosphere or pressurized.

Open channels are the most common technology used to convey water to irrigation schemes. Lining of open channels is the means of seepage control to reduce the loss of water from the source to the command area. In other words, lining is the only option to reduce the seepage loss from the canal and improve water delivery to the command area. Unlined canals are the conventional type of canals constructed where soils are mixed with clay. Conveyance efficiency is low in unlined canals and significant proportion of the water is lost along the route to the command area.

Stone masonry lining is widely practice in Bhutan which is economical in the hills as stone are available locally. However, the quality of the workmanship is not always satisfactory and can deteriorate within 5-6 years of operation. Hence, its sustainability and applicability is in question. Reinforced cement concrete (RCC) with nominal reinforcement would be appropriate solution to replace stone masonry lining (Figure 11.11). In recent years HDPE pipes have become more common for water conveyance and are seen as a better option for seepage control. Field visit shows that HDPE pipe are not properly utilized in several places however. The major issues of the HDPE pipes are related to the improper joints.

Figure 11.11: Typical conveyance canals with concrete lined section and piped canal

Concrete lined canal	HDPE piped canal
	

11.2.3 Water distribution technologies

Before describing likely technologies for water distribution, it is worth understanding water allocation and its principles. Allocation – the assignment of water – from an irrigation system to an individual farmer or a group of farmers is the means to determine who get how much water and when. In Bhutan, assignment of water in proportion to the size of the farmer's land holding (plot) in the irrigated area is the commonly used water allocation principle.

Water distribution is the process of implementing allocation principles and rules with the help of some water distribution (or division) structures and based on institutional arrangements sanctioned by the local water users. Water distribution structures can be permanent or temporary. Many water distribution methods developed by farmers consist of physical devices, which are supported by institutional arrangements to ensure that the rules of water distribution match the physical devices. Some of the widely-used methods of water distribution are: (a) Continuous flow, (b) Rotational flow, and (c) Flow on demand.

Water distribution structures in Bhutan are mostly farmer tailored proportionate dividers. At the outlet level open-cut banks are used to distribute water to the farm fields. Gated water distribution systems are found in the Taklai Irrigated System (Figure 11.12).

Figure 11.12: Gated and un-gated water distribution structures

Gated water distribution structure	Ungated water distribution structure
	

Source: ADB TA 8623 site visit

11.3 Water harvesting and micro irrigation for Dry Land Irrigation Development Project

The Dry Land Irrigation Development Project (DLIDP) presented in Chapter 8 constitutes of two main components. The first component relates to water acquisition through water harvesting, and the second to water uses through micro irrigation (sprinkler and drip). These are described below.

Water harvesting is the oldest technology of capturing water for human uses. This technology was adopted especially in arid and semi-arid regions of the Asia and Africa. Historical evidences show that a variety of water harvesting techniques had been developed in ancient times to capture, transport and use the rainwater. The basic principles of water harvesting technology relates to collecting rainfall falling in one part of the land, transfer it to other parts as surface runoff and to add to the rain that falls directly into the crops.

Micro irrigation refers to alternative methods of irrigation water application. The micro irrigation was first developed in Israel in 1960s as an efficient technology to provide water to the plant. Sprinkler and drip irrigations are the main micro irrigation technologies developed for more efficient water application. Micro irrigation technology is suitable for both small scale as well as large scale irrigation systems. They save water and are popular for smallholder farmers of arid and semiarid regions of Asia and Africa. In the context of Bhutan where small water sources are reported to be drying, micro irrigation technology could be appropriate to deal with climate change impacts and climatic uncertainties. Brief descriptions of the sprinkler and drip irrigation technologies along with their merits and demerits are presented in forthcoming headings.

This section deals with potential water harvesting technologies and micro irrigation methods.

11.3.1 Types and components of water harvesting technology

Depending on the type of water sources, harvesting technologies are categorized as rainfall or runoff harvesting, groundwater harvesting and flood water harvesting. Rainwater harvesting comprises collection and storage of rainfall runoff from various surfaces for irrigation purpose. Groundwater harvesting is the technique of abstracting water from under the ground using various tools and techniques. Flood water harvesting is one of the oldest water harvesting techniques which diverts total or part of floodwater occurred after heavy rainfall to the nearby cultivated fields. In the context of highland of Bhutan only rainwater or runoff water harvesting is feasible and forthcoming headings brief on these technologies.

The rainwater harvesting system consists of four components: (a) catchment, (b) conveyance, (c) storage facility, and (d) target area.

The catchment is the area from which the water is collected. It may be roofs, roads, paved areas, farm land, and natural hill slopes. Suitable catchments are the ones where surface and soil characteristics allow generating runoff regularly. According to the size and nature of water collection, catchments are divided into micro catchments and macro catchments. Roofs of the houses, roads and paved areas are the examples of micro catchments from where water can be harvested. Natural catchments, hill slopes and farm fields are examples of macro catchments which in general generate large amount of runoff.

The conveyance systems channel the collected runoff from the catchments to the storage facilities and consist of bunds, canals, pipes and may be equipped with control devices such as gates and stop logs. The conveyance systems are often required in larger catchments where runoff would otherwise be lost due to infiltration or where the storage facilities are located far from the catchment.

The storage facilities can be of many types including natural depressions, ponds, small reservoirs formed either by excavating soils or damming with earthen embankment, and concrete or masonry walls. The storage facilities function as buffers between water supply (rainfall) and demands. Hence, the storage capacity has to meet the water demands during dry periods.

From the storage facility water is supplied to the target area through a distribution system devised with either open channel or piped system that may be annexed with micro irrigation systems like sprinkler and drip irrigation.

Among the components of water harvesting, storage facilities are of significant importance as regard to planning and designing irrigation technologies. They are referred as pond irrigation, tank irrigation, reservoir irrigation, and low height dam irrigation.

11.3.1.1 Pond irrigation

Ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface runoff and are important sources of irrigation water in the hills and mountains where relatively small water sources are available. It is an age-old technique to catch, hold, direct and use runoff water most economically. In addition to irrigation, ponds are being used for drinking water, livestock, fish farming, fire control, landslide protection, and for recreation. Ponds are also helpful in adapting to the changes in water regime triggered by climate change. Based on the location and type of construction ponds are categorized into two types: excavated ponds and embankment ponds.

Excavated ponds

The excavated ponds are built on levelled terrain by excavating the ground surface. The soil obtained from excavation is utilized to form the embankment around the pond. In the hills such ponds are fed by surface run off while in plain areas it is fed by groundwater wherever aquifers are available. An excavated pond is generally built on a residual land or ridge of a hill where a flat area is available. This type of pond requires low maintenance, and can be built to hold more water by increasing depth if sufficient space is available for this.

Embankment ponds

Embankment ponds are the most common type of ponds which are built by earthen embankment or erecting concrete or masonry walls to retain the water. Depending upon the size, this type of pond is also referred as reservoir or tank. The common location of such pond is a natural depression or valley bottom. The pond is fed by surface runoff from its catchment area. Depending upon the size and purpose of the ponds or reservoirs, they have embankments or walls, spillways and outlets. Typical examples of excavated and embankment ponds are presented hereunder (Figure 11.13).

Figure 11.13: Excavated and embankment ponds

Excavated pond	Embankment pond
	

11.3.2 Types and components of micro irrigation

11.3.2.1 Sprinkler Irrigation

Sprinkler is a water application technology for irrigation in the form of spray resembling somewhat rainfall. The spray is obtained by the flow of water under pressure through small orifices or nozzles referred to as sprinklers. The water pressure in the sprinkler pipes can be developed either by pumping from a lower elevation or by gravity flow from a higher elevation. Sprinkler irrigation is suitable for different agro-ecological conditions particularly in water shortage area, hill slopes and high erodible soils (Figure 11.14). It is available in various designs and irrigation capacities.

Figure 11.14: Typical sprinkler irrigation plots

Sprinkler irrigation technology was first developed for larger farms to save water and labor. Initially this technology was costlier for smallholder farmers and was limited to commercial farming in developed countries. Later, non-governmental organizations have developed low cost and affordable micro irrigation kits. International Development Enterprise (IDE) has been working on low cost micro irrigation technologies in India and Nepal since 1995. Manufacturers of plastic pipes in India and other countries in this region have easily adapted this technology to meet the needs of smallholder farmers. Now various types of sprinkler kits are available on the market in this region.

Details on the components of sprinkler irrigation, and its advantages and disadvantages are given in the Irrigation Engineering Manual (TA 8623 R3, 2015).

11.3.2.2 Drip irrigation

Drip irrigation is one of the modern water application methods, which irrigates only part of the soil at the plant root zone. It consists of piped network of laterals laid down on the ground or buried at a shallow depth with low flow outlets called emitters or drippers (Figure 11.15). These emitters are designed to emit a trickle rather than a jet of water and are placed so as to produce a wet strip along the crop row or a wetted bulb of soil at every plant. This type of irrigation is usually practiced in water scarce areas for spacing crops like fruits, flowers and vegetables. It is considered as one of the most efficient methods of water application to meet the crop water requirement which needs six to eight times less water in comparison to conventional irrigation systems.

Figure 11.15: Typical drip irrigation plots

The innovation and initial development of drip irrigation took place in Israel in the 1940s. In the late 1960s drip irrigation was spread in the USA and Australia and further to several other countries in the world. In the recent years the popularity of the drip irrigation is gaining momentum mainly due to its inherent advantages like saving water and its use in all types of soil. The operating head of a drip system can vary between 5 m to 12 m which is mainly governed by the topography and size of the plot to be irrigated. The desired pressure at the inlet of the drip irrigation system is achieved either through the installation of pumping unit, or directly connecting it from the piped supply line if available pressure is adequate. Alternatively, booster pump may also be used if the pressure in the supply line is not adequate. In all cases the water may be supplied either through an elevated tank or through other systems. Pressure regulation is essential in the case of the direct connection systems.

The head unit essentially consists of valves to control discharge and pressure in the entire system. Filters are also integral part of the head unit. Depending on the quality of water one or more types of filters have to be used in the drip system.

Pipe network is the water distribution system up to the root zone of the plant. In practice two types of pipe are used for water distribution: pipe without emitters and pipe with emitters. Water from the filters is supplied to the sub-mains by means of main pipe line. Sub-main consists of number of bifurcations to connect lateral pipes or drip pipes.

Drippers are small dispensing devices and are affixed to the laterals. The main function of the dripper is to discharge consistent amount of water near the plant in form of drops. They are spaced in such a way that the emitting point is close to the plant. Some times more than one dripper is provided for one crop – especially for the matured fruit trees. For vegetables with small spacing, drippers may be closely spaced to get a continuous wetting pattern. At present various types of dripper are commercially available in the market based on the mechanism of dissipating pressure. The details on the components of drip irrigation, its advantages, and disadvantages are provides in the Irrigation Engineering Manual (TA 8623 R3, 2015)

12. Prioritized irrigation development projects and sub-projects (infrastructure)

The National Irrigation Master Plan proposes three types of projects for the development of irrigated agriculture in Bhutan. These are: project preparatory project, infrastructure development projects, and irrigation management projects. The foregoing Chapter 8 described them. This chapter presents proposed long and shortlists of prioritized irrigation infrastructure development sub-projects.

Under infrastructure development component of the NIMP, two types of irrigation development projects are proposed. These are: (a) improvement of existing irrigation systems and (b) development of new irrigation systems.

12.1 Existing Irrigation Improvement Project (EIIP)

The Existing Irrigation Improvement Project (EIIP) focuses on strengthening the existing CMISs. Three types of development supports are proposed under EIIP, as follows:

Modernization of existing irrigation systems	This will focus on expansion of the existing irrigated area utilizing existing water source. It involves enlarging existing canal capacity and thus requires re-engineering of existing infrastructure with appropriate technology. Intervention will also require institutional strengthening. Unit cost of modernization of existing irrigation systems is high.
Renovation of existing irrigation systems	This will focus on increasing the efficiency of irrigation systems and thereby increasing system's cropping intensity. It upgrades existing irrigation system by keeping the existing canal capacity as it is. So, it does not require re-engineering. The focus will be more on dry season irrigation with appropriate technological and institutional inputs. The unit cost for renovation of existing irrigation systems is lower than for modernization.
Bottleneck repair of existing irrigation systems	This will focus on providing support for bottleneck repair of existing irrigation systems on piecemeal basis. Bottleneck repair here refers to a bit more than the annual system maintenance (essentially cleaning of canals) which is being performed by the local communities. For example, if a stretch of a canal is washed away by a land slide or if a river flood erodes the existing intake, these need to be repaired, for which external support may be required. Such small bottle-neck repair of infrastructure can be designed and implemented locally. Bottleneck repairs of existing irrigation systems will be provided through local government at relatively low costs. The main objective here is to maintain the present level of production, which otherwise may decline in absence of such support.

The sections below further describe these development supports.

12.1.1 Modernization of Existing Irrigation Systems

As noted earlier, about 1212 irrigation systems presently irrigate approximately 64,248 acres. It is proposed to prioritize these systems at two levels for planning purpose. The first level of prioritization identifies candidate subprojects for modernization. The second level of prioritization[63] produces a ranked list of the best subprojects for actual implementation.

System size and availability of land and water for irrigation area expansion are the main criteria used for identifying candidate subprojects. This is explained below.

System size

Existing irrigation systems with a command area of more than 15 acres have been selected for modernization. The long list of sub-projects is presented in DOA (2013a).

Water availability

A recent study conducted by the Department of Agriculture categorized existing irrigation systems in four categories from the perspective of water availability, which is defined as abundant, adequate, inadequate or acute shortage. About 30% of the irrigation systems are said to have abundant water supply, 41% have adequate water, 20% have inadequate supply, and 9% have acute water shortage (DOA, 2013a).

Irrigation systems having abundant and adequate water supply have been selected for modernization under the NIMP.

Availability of land for expansion of command areas

The DOA irrigation database categorized command areas of existing irrigation systems as gross and net, which are defined as below (DOA, 2013a).

> *Gross Command area:* The area that is potentially/intended to be serviced by a given irrigation system. This could be either Chhuzhing or other land types.
>
> *Net Command area:* It is the actual area that receives irrigation water.

The above distinction suggests that the difference between “gross” and “net” command areas of an irrigation system corresponds to the potential area for expansion of irrigation. Considering this definition, irrigation systems having a potential for expansion of more than 10 acres have been selected for modernization. Irrigation systems whose net command areas are not known have not been included in the prioritization process.

Appendix A1 presents the complete list of selected irrigation systems for modernization. A summary per district is provided in Table 12.1

[63] Using multi criteria analysis (MCA)

Table 12.1: Summary per district of the prioritized irrigation system for modernization

SN	Dzongkhags	Irrigation systems with areas above 15 acres (no)	Gross command area (ac)	Areas under different water availability scenarios (ac)		Irrigation systems whose command areas may be extended with modernization (ac)		
				Abundant	Adequate	No	Present gross areas	Likely extension area
1	Bumthang	25	1,623	393	609	4	311	286
2	Chhukha	36	2,742	429	75	12	1,138	494
3	Dagana	94	160	692	1,606	40	4,227	2,253
4	Gasa	3	160	13	0	1	26	13
5	Haa	11	411	0	61	3	154	61
6	Lhuentse	46	4,870	297	410	18	2,548	673
7	Mongar	33	2,382	669	183	9	1,417	831
8	Paro	56	5,332	149	632	15	2,299	730
9	Pema Gatshel	9	519	0	0	0	0	0
10	Punakha	92	9,313	358	418	26	3,602	746
11	Samdrup Jongkhar	42	2,654	348	56	9	804	380
12	Samtse	30	5,216	108	453	11	1,748	551
13	Sarpang	101	10,018	39	165	5	2,254	171
14	Thimphu	28	1,809	625	282	14	1,104	906
15	Trashigang	43	3,945	45	115	5	483	135
16	Trashiyangtse	45	2,801	176	176	9	863	345
17	Trongsa	45	3,086	35	219	6	1,003	250
18	Tsirang	82	5,327	306	751	43	3,805	1,333
19	Wangdue Phodrang	99	8,814	313	948	29	3,220	1,238
20	Zhemgang	42	2,503	424	517	21	1,807	903
	Total	962	73,686	5,417	7,676	280	32,811	12,297

Table 12.1 suggests that modernization of 280 irrigation systems with a gross area of 32,811 acres have potential of expansion up to 12, 297 acres. As the NIMP targets an irrigated area expansion of only about 8,000 acres, these irrigation systems will be further prioritized using the multi criteria analysis (MCA) described in Chapter 8. Assuming that about 75% of the potential expansion can actually be feasible, about 243 irrigation systems need to be modernized for bringing an additional 8,000 acres under irrigation. Thus, the 243 irrigation systems with the gross and net areas of 28,500 acres and 18,000 acres respectively will be selected using MCA for actual modernization.

12.1.2 Renovation of existing irrigation systems

Renovation of existing irrigation system is an on-going program of the DOA. It is proposed to continue it as part of the NIMP. The main objective of renovation of existing irrigation systems is to improve irrigation efficiency and thereby increase cropping intensity. The focus will be more on dry season irrigation with appropriate technological and institutional inputs.

As noted above, the NIMP targets to improve existing irrigation systems on about 64,000 areas. Of this target, irrigation systems irrigating 18,000 acres are listed for modernization. The irrigation systems (about 335[64]) irrigating about 24,000 acres have been included in renovation category. They have been selected from the following two sources:

i. The 11th FYP proposed to renovate 76 irrigation systems irrigating 14,809 acres (Table 12.2). Appendix A2 presents the list of these irrigation systems. Of this list, about 18 irrigation systems are already included in Table 12.1 under the modernization category, and 9 irrigation systems are currently being developed (DOA, 2013). The left over irrigation systems (49 irrigation systems

64 Average irrigated area (net) per scheme in Bhutan is about 72 acres

covering 7,930 acres) have been included in the NIMP as a carryover of the prioritized irrigation systems of the 11th FYP (Table 12.2).

Table 12.2: Canal included in the NIMP renovation category as a carryover of the 11th FYP

SN	Dzongkhag	Irrigation systems proposed to be renovated under 11th FYP		Irrigation systems included in the NIMP renovation category	
		No	Areas (ac)	No	Areas (ac)
1	Punakha	6	2,211	3	814
2	Wangdue	8	1,795	6	1,044
3	Dagana	7	1,452	3	570
4	Trongsa	2	480	1	180
5	Thimphu	1	280	1	280
6	Samtse	12	3,128	6	1,127
7	Chukha	6	642	5	562
8	Sarpang	7	1,169	6	1,089
9	Tsirang	4	319	4	253
10	Zhemgang	3	280	3	280
11	Tashiyangtse	4	534	3	466
12	Mongar	3	427	1	220
13	Lhuntse	8	1,544	2	497
14	Samdrup Jo.	2	187	2	187
15	Pemagatshel	3	361	3	361
	Total	76	14,809	49	7,930

ii. Remaining irrigation systems for renovation (16,070 out of 24,000 acres) are proposed to be selected from the main list of existing irrigation systems using the multi-criteria analysis (MCA) described earlier. This selection process will be initiated during the planning exercise for NIMP implementation.

12.1.3 Bottleneck repair of existing irrigation systems

Bottleneck repair of existing irrigation systems is one of the on-going programs of the Royal Government of Bhutan, which is implemented through Gewog and Dzongkhags[65]. Presently, this program is implemented and monitored in terms of the length of canals undertaking repairs.

The NIMP proposes to continue this program. Considering three aspects, namely (a) increasing threat to these irrigation systems due to landslides and floods as a result of climate change, (b) rapidly changing socio-economic conditions of local community, and (c) increasing rural-urban migration; the external support for bottleneck repair for up keeping the operation of these irrigation systems is highly justified.

As noted above, 1212 irrigation systems presently irrigate about 64,000 acres (net). Of these, systems irrigating about 18,000 acres will undergo modernization and systems irrigating about 24,000 acres will be renovated. The remaining irrigation systems with a total canal length of about 718 km[66] irrigating 22,000 acres will be receiving support for bottleneck repairs.

[65] The 11th FYP proposed to maintain 1935 km of canals that includes 736 km of new constructions.

[66] In Bhutan, about 1995 km of canals irrigate 61747 acres (net) of land (0.032 acre per km)

12.2 Development of new irrigation systems

Depending on the local agro ecological situation where new irrigation systems are to be developed, three different types of irrigation projects are proposed, as follows:

- New Hill Irrigation Development Project (NHIDP)
- Dry Land Irrigation Development Project (DLIDP)
- Wet Subtropical Irrigation Development Project (WSIDP)

The lists of new irrigation subprojects for the above projects have been obtained from four different sources:

i. **The questionnaire survey developed by TA 8632:** The questionnaires were sent to all Gewog through the Engineering Division of the Department of Agriculture. However, only 110 Gewog responded to this questionnaire, which listed 187 new irrigation subprojects (Table 12.3). Appendix A3 presents the long list of sub-projects. This means that many other subprojects from the remaining Gewog are yet to be identified. The identified subprojects are re-grouped in different categories based on their type, technology used, and location in Table 12.3 and Table 12.4 below.

Table 12.3: List of irrigation subprojects by technology type

SN	Irrigation systems by technology	Numbers	Command areas (acres)
1	Open canal	63	6,124
2	Lift canal	37	4,339
3	Piped canal	36	2,754
4	Drip/sprinkler (clustered)	22	2,523
5	Water harvesting (clustered)	29	2,348
	Total	187	18,088

Table 12.4: List of irrigation subprojects by project category

SN	Irrigation subprojects by project category	Numbers	Command areas (acres)
1	New Hill Irrigation Development project	130	11,742
2	Dry Land Irrigation Development Project (clustered)	51	4,871
3	Wet Subtropical Irrigation Development Project	6	1,475
	Total	187	18,088

ii. **List of subprojects identified by the 11th FYP, which are yet to be implemented:** 11th FYP identified 33 new irrigation subprojects, of which 9 subprojects are already under implementation (DOA, 2013). The remaining 24 subprojects with a targeted irrigated area of 5,791 acres have been included in the NIMP as a carryover of the 11th FYP. Appendix A4 presents the list of these subprojects.

iii. **Assessment of potential subprojects made by FAO**: In 2010, FAO made an assessment of 12 potential irrigation subprojects covering an area of 6389 acres mainly in three southern districts (FAO, 2010). Appendix A5 provides the main features of these subprojects.

iv. **Assessment of potential subprojects made by ADB TA 8623**: The TA team made some assessment of potential irrigation subprojects in three southern districts of Bhutan by studying existing maps and assessing water resources. Appendix A6 provides additional information on these potential irrigation subprojects.

12.2.1 New Hill Irrigation Development Projects (NHIDP)

Of the above four sources of information for sub-projects listing, the first two (11th FYP and TA questionnaire survey) include potential subprojects for the New Hill Irrigation Development Project. These are summarized in Table 12.5. Details are provided in Appendix A3 and A4.

Table 12.5: Summary of the long list of new sub-projects under NHIDP

SN	Dzongkhags	Long list of new irrigation systems (IS), sub-projects										Remarks
		Carry over of 11th FYP		As per TA 8632 questionnaire survey						Total		
				Open canal IS		Lift canals IS		Piped canals IS		No	Area (ac)	
		No	Area (ac)	No	Areas (ac)	No	Areas (ac)	No	Areas (ac)			
1	Bumthang	1	70	2	90	1	2,000	0	0	4	2,160	
2	Dagana	1	85	8	1,717	14	811	6	248	29	2,861	28
3	Tashiyangtse	1	80	4	205					5	285	4
4	Zhemgang	1	178	10	393			1	13	12	584	11
5	Punakha			5	225	3	230	5	304	13	759	13
6	Wangdue	1	200	14	2,417	1	300	1	17	17	2,934	3 IS no data
7	Lhuentse	1	181	3	35	2	30	3	65	9	311	3 IS no data
8	Chhukha	3	300	3	62	2	42	4	239	12	643	9
9	Mongar	2	167	4	270	5	244	1	50	12	731	10
10	Trashigang	2	580	2	270	2	50	6	700	12	1,600	2 IS no data
11	Thimphu			1	30			3	95	4	125	4
12	Trongsa	1	180	5	115	4	123	5	352	15	770	14
		14	2,021	61	5,829	34	3,830	35	2,083	144	13,763	130

Note: IS refers to irrigation systems

Table 12.5 suggests that 144 new irrigation sub-projects in 12 districts have potential for irrigating 13,763 acres. This number and the total area covered will further increase when information from the remaining 95 Gewog are provided. As the NIMP aims at irrigating an additional 4,000 acres of land under the New Hill Irrigation Development Project, about 42 sub-projects will be selected from this long list using the MCA.

12.2.2 Dry Land Irrigation Development Projects (DLIDP)

The Dry Land Irrigation Development Project (DLIDP) consists of small scale water development interventions that aim to address water scarcity problems in the upper watershed of Bhutan for irrigating high value crops grown, mainly in Kamzhing. It will be an integrated project for multipurpose water uses (irrigation, domestic water supply, etc.), including components on catchment management, water supply management (canals, tanks) and water application (drip, sprinkler, furrow or direct application, etc.).

People's experience of such irrigation systems in Bhutan is limited. However, farmers are in demand of several water supply and water use systems like water tank, water harvesting, drip irrigation, sprinkler irrigation, small dams, and so on. These are grouped under the DLIDP.

Appendix A3 provides a long list of clusters of potential irrigable areas identified by the communities of 110 Gewog through the TA 8632 questionnaire survey (see above) that could be irrigated by small scale water projects. These were further categorized into two groups based on the type of technology concerned (Appendix A3). A summary is given per district in Table 12.6

Table 12.6 : Summary per district of small scale water projects identified by communities

SN	Dzongkhags	Sub-projects identified		Drip / Sprinkler		Water harvesting / dam / tank		Remarks
		No	Areas (acres)	No	Areas (acres)	No	Areas (acres)	
1	Bumthang	1	500	1	500	0	0	
2	Dagana	12	290	4	59	8	231	
3	Wangdue Phodrang	8	1,027	3	362	1	665	No data on 4 systems
4	Zhemgang	2	60	0	0	1	60	No data on 1 system
5	Punakha	13	1,850	5	1,280	7	570	No data on 1 system
6	Chhukha	10	532	8	302	2	230	
7	Mongar	3	74	0	0	3	74	
8	Trashigang	8	538	1	20	7	518	
		57	4,871	22	2,523	29	2,348	

Note: This is not the complete list. It corresponds to a listing from only 57 Gewog.

Table 12.6 suggests that a total of 57 clusters of subprojects in respective Gewogs consisting of water harvesting (tank, pond, dam), and drip / sprinkler irrigation systems could irrigate about 4,871 acres. This means that in each Gewog a cluster of the water harvesting and drip / sprinkler system would command an average area of 100 acres. Considering an average coverage of 10-15 acres per system, each Gewog would contain about 7-10 such systems.

As the NIMP through the DLIDP targets to irrigate a land area of 4,000 acres (preferably Kamzhing) in the upper watershed of the country, about 320small scale integrated water projects (10-15 acres per system) will be selected for implementation using the MCA.

12.2.3 Wet Subtropical Irrigation Development Project (WSIDP)

As noted above, the Wet Subtropical Irrigation Development Project (WSIDP) covers southernmost narrow strips of the low altitude wet subtropical zone of the three southern Dzongkhags. It aims at converting rain-fed Chhuzhing into irrigated Chhuzhing through the development of irrigation infrastructure by acquiring water from nearby new water sources. Table 12.7 summarizes the proposed irrigation subprojects per district under WSIDP.

Table 12.7 : Summary of the proposed irrigation subprojects per district under WSIDP

SN	Dzongkhag	Potential irrigable land (acres)			Proposed irrigation sub projects (new)		Data source	Reference
		Rainfed Chhuzhing	Kamzhing	Total	No	Areas (ac)		
1	SamdrupJongkhar	1,022	9,843	10,865	2	180	11th FYP	Appendix A4
					2	2,503	FAO identified	Appendix A5
					2	515	TA 8632 planned	Appendix A6
				Total	**6**	**3,198**		
2	Sarpang	1,146	7,817	8,963	6	1,475	TA 8623 survey	Appendix A3
					7	4,531	FAO identified	Appendix A5
					1	1,500	TA 8632 planned	Appendix A6
				Total	**12**	**7,506**		
3	Samtse	13,248	13,561	26,809	8	3,590	11th FYP	Appendix A4
					3	1,789	FAO identified	Appendix A5
					15	7,794	TA 8632 planned	Appendix A6
				Total	**26**	**13,173**		
		All Dzongkhags total			**44**	**23,877**		

Table 12.7 suggests that 44 new subprojects in 3 districts have potential for irrigating an area of 23,877 acres, most of which being rainfed Chhuzhing. As the NIMP through the WSIDP targets to irrigate an area 11,000 acre, about 20 subprojects will be selected for implementation using the MCA.

12.2.4 Summary of proposed new irrigated areas

As noted above, new irrigated areas are to be developed either by modernizing the existing irrigation systems or by building new irrigation systems under several irrigation development projects. Foregoing sections provided long lists of subprojects that need further screening prior to implementation.

Two approaches have been adopted for the district wide screening of irrigation sub-projects for the NIMP. In the case of general subprojects, these were screened in proportion to the existing irrigated area of the concerned district. In the case of specific sub-projects (for example projects being carryovers of the 11th FYP), all of them were included in the shortlist as they are already considered to be feasible. Table12.8 presents summary per district of the proposed new irrigated areas.

Table 12.8: Summary per district of the proposed new irrigated areas

SN	Dzongkhags	Planned new irrigated areas under several projects (acres)				
		Existing Irrigation IP	New Hill IDP	Dry lands IDP	Wet subtropical IDP	Total
1	Bumthang	186	78	16		280
2	Chhukha	321	396	195		913
3	Dagana	1,465	277	388		2,131
4	Gasa	8	5	11		24
5	Haa	40	12	25		77
6	Lhuentse	438	342	325		1,104
7	Mongar	540	226	119		885
8	Paro	475	166	335		976
9	Pema Gatshel	0	18	35		53
10	Punakha	485	350	708		1,543
11	Samdrup Jongkhar	247	0	0	1,202	1,449
12	Samtse	358	0	0	5,707	6,066
13	Sarpang	111	0	0	4,091	4,202
14	Thimphu	590	29	58		676
15	Trashigang	88	741	326		1,155
16	Trashiyangtse	224	187	216		628
17	Trongsa	162	289	219		670
18	Tsirang	867	154	311		1,333
19	Wangdue Phodrang	806	501	609		1,916
20	Zhemgang	587	229	103		919
	Total	8,000	4,000	4,000	11,000	27,000

13. Irrigation development cost, investment plan, and likely benefits

The irrigation development roadmap outlined earlier in chapter 8 categorized NIMP investments into three groups, as follows:

- Investments for project preparation
- Investments for infrastructure development, and
- Investments for irrigation management and institutional strengthening

This section first presents interventions costs followed by an investment plan and expected benefits.

13.1 Costs for project preparation

The projects and sub-projects identified in the NIMP will need to be further studied in terms of their feasibility, detail design, and for project preparation. Besides this, several specific studies are required for irrigation development. The Appendix B1 details the costs for project preparation, which amounts to USD 6.4 million.

13.2 Costs for infrastructure development

Cost of irrigation infrastructure for the different irrigation development projects / subprojects considered under the NIMP have been estimated by using unit costs from on-going and recently completed irrigation development projects in Bhutan and in other countries in the region.

13.2.1 Cost escalation factor

As former costs date back to different time frame in the past, a cost escalation factor has been adopted as presented in Table 13.1

Table 13.1 : Cost escalation factor

Year when original costing was done	Cost escalation percentage for estimating present costs
2015	
2014	10
1013	15
2012	20
2011	25
2010	30
2009	35

A currency conversion rate of 1:64 (USD to NU) has been adopted for costing. The sections below explain how the unit costs of irrigation subprojects under the NIMP were calculated.

13.2.2 Unit costs of irrigation subprojects under the NIMP

Unit costs here refer to the cost of infrastructure development for sub-projects under the main project categories defined in the NIMP.

13.2.2.1 Existing Irrigation Improvement Project (EIIP)

The Existing Irrigation Improvement Project (EIIP) includes the following:

Modernization of existing irrigation systems

Modernization involves re-engineering of existing irrigation systems and their structures. In 2015, the Royal Government of Bhutan (RGoB) through DOA initiated modernization of 11 irrigation subprojects (5 in wet subtropical areas and 6 in middle mountain) under “Improvement of Irrigation Infrastructure & Arable Land Development (FIC 2963)” funded by the Government of India. Estimated unit cost of these subprojects for Middle Mountain and Wet Subtropical regions are 62,600 and 57,700 Nu per acre respectively (Appendix B4).

Likewise, the 2015 unit costs for the modernization of similar irrigation subprojects in Nepal and Afghanistan come out to be at 72,968 and 46,186 Nu per acre (Appendix B4). Higher costs of construction materials in Nepal (due to higher taxation rate) explain the higher unit cost for irrigation modernization, while the lower rate of construction materials in Afghanistan along with relatively larger size of the irrigation systems explain the lower unit cost.

Using on-going irrigation modernization costs in Bhutan, a unit cost of 60000 Nu per acre is adopted for irrigation modernization under the NIMP. This is equivalent to 940USD per acre.

Renovation of existing irrigation systems

Renovation of existing irrigation systems involves essential structural improvements (ESI). It focuses on replacing temporary structures by a more durable ones, reshaping of canals, and building water control structures where needed with an objective of enhancing system’s efficiency. This does not involve re-engineering of irrigation systems.

Based on a detail study conducted by JICA in 2012 (Volume 3), renovation cost of existing irrigation systems in the Samste District has been estimated at 13,328 Nu per acre (Appendix B5). Following this estimation, NIMP adopts 17,600 Nu per acre[67] as the unit cost for renovation of existing irrigation systems in Bhutan. This is equivalent to 275 USD per acre

Bottleneck repair of existing irrigation systems

Bottleneck repair involves fixing bottle neck structures along canals that have been damaged either by natural calamity or by some other reasons, and whose maintenance is beyond the capacity of the farmers. Such interventions will be made on piecemeal basis.

The JICA’s study conducted in the Smste District in 2012 suggests that about 1,999 Nu/acre may be required for providing support for the bottleneck repair of these irrigation systems. Using this estimation, the NIMP adopts 2,640 Nu per acre as bottleneck repair unit cost. (Appendix B5). This is equivalent to USD 40 per acre and USD 102 per ha.

The above figure is in line with the unit cost of USD 105 per ha estimated for up keeping traditional irrigation systems in operating condition in Afghanistan (HRBMP, 2013)

[67] This includes extra 10% for accounting additional costs likely to be encountered in renovating canals in the middle mountain regions

13.2.2.2 New Hill Irrigation Development Projects (NHIDP)

Subprojects under the New Hill Irrigation Development Project (NHIDP) involve construction of some of the irrigation infrastructure that irrigates both the Kamzhing and Chhuzhing of the targeted area. In most cases, new construction involves construction of irrigation intake through water source diversification, feeder canal, and extension of distribution canals to Kamzhing.

The base cost for such new subprojects is similar to the cost for modernizing an existing irrigation system plus an additional cost for the development of a new intake at the water source and feeder canal.

With this consideration in mind, the NIMP estimates that the unit cost for new irrigation subprojects under NHIDP will be 1.5 times the unit cost of the modernization of irrigation systems in the middle mountain areas. It is therefore assumed that the unit cost for new irrigation subprojects under NHIDP will come to Nu 94,000 per acre. This is equivalent to USD 1,470 per acre or USD 3,631 per ha. This figure is in line with the unit cost of irrigation development in Nepal and Afghanistan[68].

13.2.2.3 Dry Land Irrigation Development Project (DLIDP)

A subproject under the Dry Land Irrigation Development Project (DLIDP) mainly includes three subcomponents namely (a) catchment management, (b) water supply system, and (c) water distribution system. Presently, the World Bank funded Remote Rural Communities Development Project (RRCDP) is implementing small and micro irrigation in Bhutan with a focus on water supply systems like water harvesting, tank, ponds, small lifts, etc. Average cost per acre for such water systems (supply side) is Nu 70,000 per acre (Appendix B6).

Water distribution system like drip, sprinkler, pipe network for direct application, and open canals will be relatively cheaper compared to the costs required for water supply. Assuming that one third of the cost of water supply system will be required for each of the water distribution system and catchment management, the total unit cost of a subproject under DLIDP has been estimated to be 116,000 Nu per acre. This is equivalent to USD 1,800 per acre or USD 4,500 per ha.

13.2.2.4 Wet Subtropical Irrigation Development Project (WSIDP)

As in the case of New Hill Irrigation Development Project, the unit cost of subprojects under the WSIDP will also be 1.5 times the unit cost for the modernization of irrigation systems in the same region. With this assumption, the unit cost of new irrigation subproject under WSIDP will be Nu 86,500 per acre. This is equivalent to USD 1,350 per acre and USD 3,335 per ha.

13.3 Annual operation and maintenance costs of the developed irrigation systems

All existing irrigation systems in Bhutan (irrigating about 64,000 acres) have been managed by local communities since long. Operation and maintenance (O&M) is done through community participation that is partly governed by local social norms and values. The maintenance of these irrigation systems is labor intensive.

Irrigation improvement under the NIMP will involve the replacement of existing temporary irrigation infrastructures by a wide variety of permanent structures that may require foreign materials like reinforced concrete, steels, pipes, pumps, and others for building and/or installation. The new irrigation infrastructures will certainly demand some capital for their maintenance. So, the irrigation systems that

[68] The 2012 unit rate of new irrigation systems in Afghanistan is USD 3300 per ha. The present rate would be 3300*1.2 (3960 per ha). Likewise, average unit cost of new irrigation systems in Nepal (at present rate) is USD 5800.

used to be maintained mainly through the mobilization of local labor force will require capital resources for maintenance after construction.

Chapter 8 provides the road map for the maintenance of newly developed irrigation systems. The road map states that until the WUAs become technically and financially sustainable, communities will require external support for annual repair and maintenance for the more technically demanding (sophisticated) facilities. Assuming that about five years will be required for the community to become technically and financially sustainable, until then about 50% of the O&M cost shall be provided by the government either through the regular budgeting systems or through the proposed Central Irrigation Maintenance Fund.

With the above assumption, and also considering that about 3% of the sub-project infrastructure cost is usually required for annual O&M, total O&M cost of developed facilities is about USD 5 million

13.4 Land development and agriculture mechanization costs

As noted earlier, land development and agriculture mechanization includes three components described below

13.4.1 Land development

Land development is an on-going program of the Royal Government of Bhutan. The 11th five year plan has allocated a capital budget of 7 million Nu (about 110,000 USD) for terracing 1,000 ha for horticulture and cash crop production. Deployment of machineries for land development is the main activity for this output, which benefits dry land and orchard owners.

Under NIMP, this program will be implemented in conjunction with the three irrigation development projects that aim to bring an additional 16,000 acres of rain-fed areas under irrigation. These projects concern the modernization of existing irrigation systems under the Existing Irrigation Improvement Project (EIIP), the New Hill Irrigation Development Project (NHIDP), and the Dry Land Irrigation Development Project (DRIDP). It is assumed that about half of this land (8,000 acres) will consist of Kamzhing that will undergo land development.

The 11th FYP allocated USD 45 per acre for land development (capital cost). However, this amount seems to only take into account the mobilization of equipment. Unit cost of land development as per NIMP estimate is much higher and amounts to USD 1,400[69] (Appendix B7).

13.4.2 Agricultural mechanization

Activities under agricultural mechanization will include:

- Provision of farm machinery, and
- Strengthening public private partnership, and community participation for support services.

As noted above, the agricultural mechanization component of the NIMP aims to mechanize agriculture over an area of about 15,000 acres by 2032. This program will be implemented in conjunction with the other irrigation development projects. However, focus will be provided to those locations that include several existing irrigation systems which have available areas for irrigation expansion, and which are close to market centers for establishing maintenance support units for machineries.

The 11th FYP allocated a capital budget of 340 million Ngultrum for mechanizing agriculture over an area of 3,729 acres. The allocated budget will be used for promoting mechanization services through farmer support service unit (FSSU), hiring services, mobile clinics, supply of machineries and including privatization. With this allocation, unit cost of mechanization per acre comes out to be Nu 91,177 or USD

69 Part of this cost (rate) may be financed by the concerned land owner

1,425. Considering normal inflation of 20%, NIMP proposes to allocate USD 1,700 for mechanizing one acre of land (Appendix B8).

13.4.3 Development of on farm trail

On-farm trails shall facilitate the movement of small farm machineries within irrigated areas and facilitate agriculture mechanization. These are proposed to be developed along the main and branch irrigation canals, especially utilizing canal right of way. They will be low cost small trails with an average width of 2.5 m, to be built through community participation using local knowledge, skills, labor and materials.

The on-farm trail development program will be implemented in conjunction with the agricultural mechanization component of the LDAMP, and thus will cover an area of 15,000 acres. Unit rate for the development of “on farm trail” is about USD 100 per acre (Appendix B9).

13.5 Costs for integrated crop and water management

Cost components of the Integrated Crop and Water Management Project (ICWMP) include: (a) participatory diagnostic learning and action planning, (b) capacity building on ICWMP through farmer field school (FFS), (c) resources for demonstration plots (irrigation and agriculture) (d) supply of improved seeds, saplings, fertilizers etc. to farmers at subsidized rates (e) market promotion (f) technical assistance and agricultural extension.

As noted before, the ICWMP will be implemented through a two-pronged approach, namely sector wide and project specific.

The unit cost for sector wide approach of the ICWMP is estimated at around USD 500 per acre, while the unit cost for Taklai ICWMP is USD 750 per acre (Appendix B10). This is because the Taklai ICWMP also includes modernization of water distribution systems besides general activities under integrated crop and water management.

13.6 Institutional development and capacity building costs

The institutional development and capacity building component of the NIMP aims to strengthen DOA (central and regional), district development organizations, WUAs, and private sector consultants for efficient implementation of the NIMP. This includes the following:

- Physical facilities.
- Formation of WUAs and their federation.
- Water resource database, computer based engineering software, web-based irrigation design system, and manuals / guidelines.
- Capacity building of the government staffs and members of WUA through higher studies (Msc), trainings, and study tours.
- Capacity building of private sector for engineering design and project preparation.

The total estimated cost for this component is USD 5.75 million. Appendix B2 provides detailed cost breakdown.

13.7 Costs for implementation support services

The Engineering Division of the Department of Agriculture has a limited staff. As a result, it cannot provide human resources for implementation support services that include studies during construction, construction supervision, contract management, monitoring and evaluation, safeguard management, and other related services. The NIMP thus aims to out-source these tasks to national / international consulting firms.

The estimated cost for implementation of support services for irrigation development is estimated at USD7.4 million. Appendix B3 provides the details.

13.8 Summary of irrigation development costs

Table 13.2 presents summary of irrigation development costs. It amounts to a total of USD140 million.

Table 13.2: Summary of costs (NIMP)

SN		Key projects of NIMP	Unit	Target	Rate (USD)	Costs (USD)	Sub total
1		Project Studies and Preparation (PSP)				6,400,000	
2		Infrastructure development					
	2.1	Existing Irrigation Improvement Project (EIIP)					
		Modernization of Existing Irrigation Systems	Acre	26,000	940	24,440,000	
		Renovation of Existing Irrigation Systems	Acre	24,000	275	6,600,000	
		Bottleneck repair of Existing Irrigation Systems	Acre	22,000	40	880,000	
	2.2	New Hill Irrigation Development Projects (NHIDP)	Acre	4,000	1,470	5,880,000	
	2.3	Dry Lands Irrigation Development Projects (DLIDP)	Acre	4,000	1,800	7,200,000	
	2.4	Wet Subtropical Irrigation Development Project (WSIDP)	Acre	11,000	1,350	14,850,000	
				91,000			59,850,000
3		Annual O&M of developed irrigation facilities	Acre			5,000,000	5,000,000
4		Land Development and Agricultural Mechanization Project (LDAMP)					
	4.1	Land Development	Acre	8,000	1,400	11,200,000	
	4.2	Agricultural Mechanization	Acre	15,000	1,700	25,500,000	
	4.3	On Farm Trail Development	Acre	15,000	100	1,500,000	
							38,200,000
5		Integrated Crop and Water Management Project (ICWMP)					
	5.1	Sector Wide Implementation of ICWM	acre	30,000	500	15,000,000	
	5.2	Taklai ICWMP including Development of Distribution System	acres	3,200	750	2,400,000	
							17,400,000
6		Institutional Strengthening and Capacity Building				5,750,000	
7		Implementation Support Services				7,400,000	
					Total	140,000,000	

13.9 Investment plan

The total planned investment for the NIMP over the next 15 years amounts to about 140 million US dollars. It is expected that actual implementation will start from the fiscal year 2016 /17 which begins in July 2016. This means that the last two years of the 11th FYP will overlap with the implementation of the NIMP.

As the investment ceiling of the 11th FYP (2013-2018) has already been fixed, the NIMP investment plan for the first two years is kept in line with the already allocated budget of the 11th FYP. This figure amounts to about USD4.5 million per year (irrigation sector).

Further examination of the past expenditures made by the Engineering Division of DOA suggests that the division is capable of managing an average expenditure of only about 2.6 million per year. In this sense, a priority of the NIMP during its first few years of implementation is to enhance the capacity of DOA, the district engineers, and WUA.

Recognizing this, the NIMP aims to only invest about 4 to 5 million USD per year on infrastructure and land development during the first two years of its implementation. Thereafter, the investment will sharply rise to about 11 million USD per year.

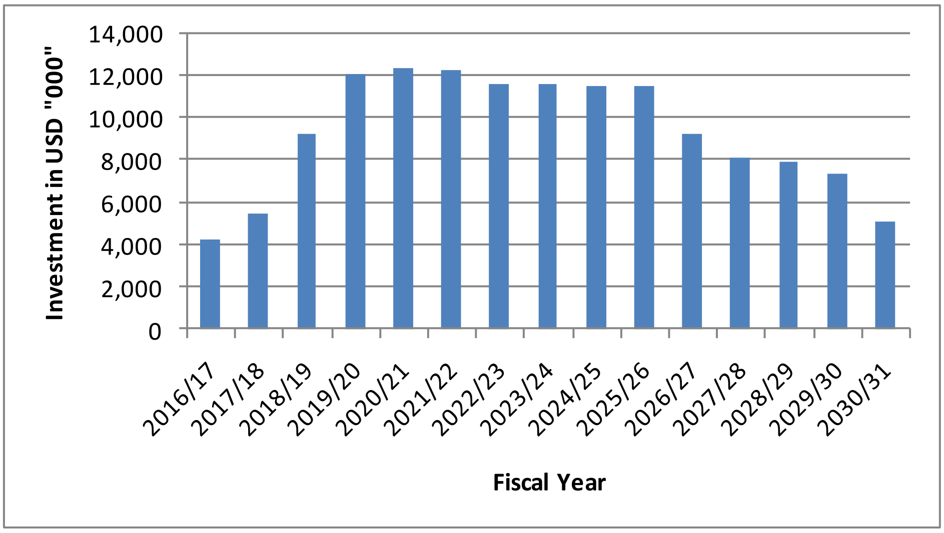
Table 13.3 presents the implementation schedule of the various components of the NIMP and Figure 13.1 provides a summary of the investment plan in the form of a bar chart.

Table 13.3: Implementation schedule and investment plan of the key components of the NIMP

Fiscal year	Investments (US$) in 000								
	Project studies & preparation	Infrastructure		Land development	Integrated crop and water management		Institutional development	Implementation support services	Total
		Capital	O&M		Sector wide	Taklai			
2016/17	700	2,000		1,000	0	0	550		4,250
2017/18	1,000	2,750		1,000	0	0	750		5,500
2018/19	2,000	3,000		1,500	1,000	400	1,000	400	9,300
2019/20	1,700	4,000	417	2,000	1,000	700	1,500	750	12,067
2020/21	1,000	4,000	417	3,000	1,200	1,000	1,000	750	12,367
2021/22		5,000	417	4,000	1,300	300	500	750	12,267
2022/23		5,000	417	4,000	1,300		150	750	11,617
2023/24		5,000	417	4,000	1,400		100	750	11,667
2024/25		5,000	417	4,000	1,300		100	750	11,567
2025/26		5,000	417	4,000	1,300		100	700	11,517
2026/27		4,000	417	3,000	1,200			700	9,317
2027/28		4,000	417	2,000	1,100			600	8,117
2028/29		4,000	417	2,000	1,000			500	7,917
2029/30		4,000	417	2,000	1,000				7,417
2030/31		3,100	417	700	900				5,117
	6,400	59,850	5,000	38,200	15,000	2,400	5,750	7,400	140,000

Source: ADB TA 8623 planned

Figure 13.1: NIMP annual investment plan expenditure in summary



13.10 Benefits from NIMP investments

Benefits from the investment plan of the NIMP will be of two types: direct and indirect. The paragraph below first outlines some of the indirect benefits. This is followed by direct benefits.

13.10.1 Indirect benefits

Below are some of the main indirect benefits of investment on irrigation development in Bhutan:

Food security	One of the prime benefits will be the increased level of food security in the country, which is self-explanatory
Rural employment generation	It is expected that the development of irrigated agriculture in the country will substantially increase employment opportunities along the various steps of the value addition chain (production, processing, transporting, and marketing). This shall enhance rural income and thus help reduce rural urban migration.
Support development of livestock	Livestock is an integral part of the farming systems in Bhutan, and its development is prerequisite for maintaining nutritional value of food consumption. With the development of irrigated agriculture, supply of livestock feeds will increase partly through crop residues and partly through the production of both cereals and green biomass as animal feeds. This is especially true in the case of spring maize, which is also considered as a fodder crop.
Supports micro agro industries	It is expected that development of irrigated agriculture will support micro agro industries (agri-business) in rural towns that will generate employment opportunities and thus help reduce rural urban migration.

13.10.2 Direct benefits

As noted above, direct benefits relate to the increase in yield and crop production. It is expected that the overall cropping intensity will increase from the present level of about 103% to about 159%. Table 13.4 presents likely cropped area, yield and production of main crops before and after irrigation.

Table 13.4: Areas yield and production of major crops before and after irrigation

Principal crops	Before irrigation			After irrigation			Production cost		Farm gate price (Nu/Kg)
	Area (Acre)	Yield (Mt/ac)	Production (MT)	Area (ac)	Yield (Mt/ac)	Production (MT)	(Nu/kg)	% labor cost	
Paddy (Middle mountain & valleys)	32,190	1.45	46,793	46,973	1.93	90,658	19	82	22
Paddy (Southern Districts)	21,460	1.45	31,196	31,315	1.93	60,438	13	79	14
Wheat	4,860	0.92	4,495	10,955	1.20	13,102	16	43	27
Summer maize	13,420	1.19	16,030	400	1.43		16	43	21
Spring maize		1.40		10,624	1.82	19,335	16	43	25
Legume / Oilseed	4,130	0.39	1,600	10,368	0.50	5,221	57	41	44
Potato (summer)	1,680	3.76	6,317	2,544			11	44	19
Winter potato				10,536	6.00	63,219	11	44	19
Orchards	2,350	2.48		11,968	3.22	38,507	8	25	27
Vegetables	4,470	0.99	4,410	10,768	1.28	13,812	22	64	77
Other cereals (millet / barley)	5,850	0.61	3,584				16	43	31
Total	90,410			146,451					

Sources: (a) For scenario before irrigation and production costs: DOA AS (2012, 2013); RNR Statistics (2011, 12 and 15); and some DOA unpublished data, (b) for scenario after irrigation: Assessment made by ADB TA 8623

13.11 Economic evaluation

The objective of increasing the agricultural production is not primarily, or at least solely, driven by an economic rationale. It is rather driven by the Bhutan's political commitment toward maintaining food security. As this planning objective is influenced by several socio-economic considerations like people's wellbeing, culture, security, and sovereignty, it is not straightforward to provide economic justification of the NIMP. However, attempts have been made in evaluating the proposed investment on NIMP from an economic perspective. These are summarized below. Details of this economic evaluation can be found in the ADB TA economic evaluation report (TA 8623 R8, 2016)

13.11.1 Investment and benefits

As noted above, total investment of the NIMP amounts to 140 million USD, which is planned to be invested over the next 15 years starting from the FY 2016 / 2017. Figure 13.1 presents an investment plan. Likewise, expected benefits are of two types: direct and indirect. Direct benefits relate to increase in yield and crop production, which are summarized in Table 13.4. Similarly, enhancement on food security, increase in employment opportunity, support to livestock development, and development of climate resilient agriculture system are some of the indirect benefits that are harder to quantify.

13.11.2 Approach and methodology of economic evaluation

In principle, an economic evaluation is simple: it compares the present value of both the investment and benefits at a common discount rate. However, it turns out that contextualization of such rationale is not straightforward to perform.

Indeed, sizeable projects of the kind, as well as the particular nature of public investment require to pay a particular attention to a number methodological issues, like the definition of costs and benefits, the baseline scenario, the discounting, as well as the management of uncertainties, such as climate variability. Details are available in the economic report.

In a nutshell, the approach compares two options: one with the proposed investment (the project option), and one without NIMP implementation or "baseline scenario". The results are presented both statically, i.e. key economic indicators are computed as numbers, as well as in a non-deterministic fashion, or probabilistically. In this case, economic indicators would appear as a probability distribution, thus providing a finer view of the likelihood of the realization of any value on its own range. Results are disaggregated along discount rates.

A necessary condition for the investments to be economically worthy are that the value of the production under the NIMP is greater than the value of the production without, i.e. that the Benefit over Costs ratio (B/C) is bigger than one.

13.11.3 Assumptions

The detailed methodology is to be found in the economic evaluation report. The following important assumptions were made in this evaluation:

- Conservative principle was applied: in case of doubt, values or ranges of values that lie more on the "pessimist" side with respect to project evaluation are used. The aim is to avoid over confidence and overly optimistic evaluations. By the same token, it strengthens positive conclusions, as the latter are more robust. It is also a matter of knowing where the bias is more likely to bend.
- The food production always finds a buyer, in spite of possibly existing cheaper alternatives (Indian imports). Though far from granted, this assumption should not either be considered as a so-called "heroic", i.e. unreasonably optimistic. Indeed, it is fair to expect that local prices are inter alia informed by the Indian imports, and hence that they (partially at least) adjust to it. It is also worth noting that even if not all what is produced is sold, some can be stocked piled, including to buffer for times of shortage (cereals mainly). It is therefore surely not all lost anyway[70].
- Climate change is expected to induce the following variations in crop yields :

  Paddy – middle mountain range: -1.2%
  Paddy – Southern foothills: -3.2%
  Wheat: + 6.7%
  Maize: -5.9%
  Millet and barley: -7%
  Legume, oilseed: -6%
  Potatoes: -6%
  Orchard: -6%
  Vegetables: -6%

- In the probabilistic analysis, all distributions are of PERT type. The PERT (« Program Evaluation and Review Technique ») is similar to a triangular distribution as it takes three parameters (min value, most likely and max value). It is considered superior to triangular distribution for its smooth shape is more suited to account for asymmetries in lopsided distributions. The most likely value is considered to be the static case. Below are the minimum and maximum values used:

  For all crops (11 types) before irrigation: -20%; +6%
  For all crops (11 types) after irrigation: -10%; +10%
  Costs: -5%; +15%
  Farm gate price: -2.5%; +5%
  Investments: -2%; 25%

13.11.4 Results

The results are unambiguous: the NIMP is clearly worth implementing. Statically, the B/C is above 2 across all discount range while the NPV in centered to around USD 100 million. Even under pretty conservative probabilistic assumptions the NPV worst 10% quantile is above USD 40 million and the

70 These assumptions were built and confirmed after the TA exchanged views with the agricultural marketing department.

best 90% quantile at USD 86 million across all discount range, while the B/C ratio ranges between 1.5 and 2.

Table 13.5 summarizes the outcome of this economic evaluation in terms of IRR, BC ratio, and NPV[71] of the investment against the targeted benefits of NIMP at different discount rate.

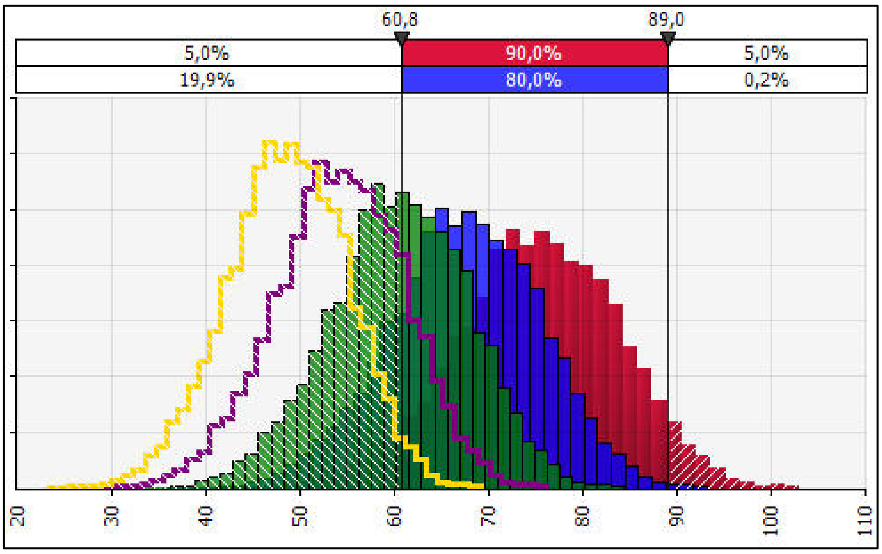
Table 13.5: IRR, BC ratio and NPV of the NIMP investment

	discount rate	8%	9%	10%	11%	12%
NPV - MUSD	mean	75,4	67,5	60,5	54,2	48,6
	median	75,5	67,6	60,6	54,3	48,7
	10%	64,4	57,4	51,1	45,5	40,5
	90%	86,1	77,4	69,7	62,7	56,5
B/C	mean	1,85	1,80	1,75	1,71	1,67
	median	1,85	1,80	1,75	1,71	1,67
	10%	1,72	1,68	1,63	1,59	1,56
	90%	1,97	1,92	1,87	1,82	1,78
IRR	mean	37%	37%	37%	37%	37%
	median	37%	37%	37%	37%	37%
	10%	33%	33%	33%	33%	33%
	90%	42%	42%	42%	42%	42%

Source: Economic evaluation report of the ADB TA 8623 (TA 8623 R8, 2016)

Likewise, Figure 13.2 presents the probability distribution of the net present value (NPV) for 8% to 12% discount rate (8% in yellow, 9% in purple, 10% in green, 11% in blue, 12% in red)

Figure 13.2 NPV probability distributions for 8% to 12% discount rates



Source: TA 8623 R8 (2016)

Clearly, Figure 13.1 suggests that even under the worst scenario (the lowest point of the distribution for the highest discount rate), the NPV still almost to USD 40 million, which still yields a B/C of about 1.5 overall. It thus appears that the NIMP is worth implementing.

About results robustness

[71] IRR, BC ratio, and NPV refer to (a) internal rate of return, benefit cost ratio, and net present value respectively

Probabilistic assumptions were conservative, so the conclusion is considered very robust with respect to the economic worthiness of the NIMP as conceived.

Indeed, the economic analysis relative to the NIMP is not much sensitive to changing of scale. There is no scale economy rationale or the like, hence the conclusion are somewhat linear relative to the NIMP. If one wants to abstract from the scale of the project, perhaps the most suitable indicator to look at is the B/C ratio. The probabilistic analysis suggests that it is ranging from 1.5 to 2 across discount rates and quantiles of the B/C probability distribution.

14. M&E plan and recommendations

14.1 M&E plan

This Monitoring and Evaluation (M&E) plan has been prepared not only to track progress of the NIMP but also to learn from its implementation so that it can be timely corrected, reoriented or adjusted for greater performance while still underway.

Data collection is one of the key tasks of M&E. This requires dedicated organization unit. Recognizing this, the Chapter 10 on "institutional strengthening and capacity building" has proposed to establish an "operation, maintenance and research" unit under the Irrigation and Water Management Section of DOA's Engineering Division. This unit will be responsible for overall M&E of the NIMP.

Regular progress monitoring will be carried out mainly for input, activities, output, and outcome of the NIMP through the use of several forms and formats as prescribed by the Policy and Planning Division of the Ministry of Agriculture and Forest. With regard to the inputs, annual budget allocation and expenditure will be monitored.

Table below presents a framework with performance measures, indicators and targets for monitoring activities, outputs, outcome and goal of NIMP. This framework presents only those performance indicators that are directly related to irrigation development.

Summary	Performance measures and Indicators with 2014 baselines	Performance target by 2032
Goal: Food and nutritional security enhanced	Food self-sufficiency in paddy (rice) increased (Baseline: 51%)	75%
	Food self-sufficiency in total cereals increased (Baseline: 64%)	80%
Outcome		
Agricultural production enhanced	Cropped areas under paddy crop increased: (Baseline: 53,659 ac)	78,288 ac
	Cropped areas under total irrigated cereals increased: (Baseline: 77,789 ac)	100,267 ac
	Cropped areas under cash crop increased: (Baseline: 12,630 ac)	46,184 ac
	Cropping intensity of irrigated agriculture increased: (Baseline: 110%)	159%
	Agricultural production increased: Baselines: Paddy: 77,149 Mt Cereals: 170,000 Mt (total)	Paddy: 145,000 Cereal: 292,000
	Yields of main crops increased Baselines (Mt / ac) Paddy: 1.45 Maize:1.40	Paddy: 1.93 Maize: 1.82

	Wheat: 0.92	Wheat: 1.20
Institutional capacity (DOA, WUA, Private sector) enhanced	Project implementation and management capacity of DOA increased:	
	Number of registered WUA increased	
Outputs		
Project implementation support	• Subprojects are ready for implementation • Sectoral studies are completed	
Development and management of irrigation system	• Existing irrigation systems strengthened and managed (72,200 ac) • New irrigation systems developed and managed (19,000 ac) • Land management ➢ Land development completed (8000 ac) ➢ Agricultural mechanization and development of on farm trails in 15,000 acres of land completed • Water management and crop production enhanced in 33,200 acres of land	
Institutional development	• Irrigation and Water Management Section (IWMS) under the DOA's Engineering Division is established with adequate staffs • Operating framework of IWMS established • Training imparted to IWMS staffs and WUAs • WUA federated	

Activities
• Project studies and preparation • Strengthening of existing irrigation (64,000 acres) • Development of new irrigation systems (27,000 acres) • Land development and agricultural mechanization (15,000 acres) • Integrated crop and water management project (33,200 acres) • Institutional strengthening and capacity building project • Project implementation support

14.2 Assumption and risks

This NIMP has been prepared considering the prevailing challenges and opportunities of irrigated agriculture. It assumes that the present political commitment for the development of irrigated agriculture in Bhutan would continue with appropriate support from the government. Withdrawal of this commitment will be the main risk in implementing this plan. Other associated risks are:

- Lack of attention to agricultural and land management issues such as commercialization of agriculture, and land consolidation and land pooling
- Inadequate funding to agriculture sector and irrigation sub-sector
- Inadequate subsidies on agriculture sector
- Lack of attention to legal issues
- Weak institutional capacity on project design, implementation and management
- Inadequate consideration on bilateral trade with neighboring countries
- Lack of coordination with other agencies engaged in irrigated agriculture and water resources management
- Government procedures of development of irrigated agriculture non-responsive to this plan

14.3 Recommendations for other support

This NIMP presents a road map for the development of irrigation in Bhutan for meeting the national target on food security. The road map constitutes of four components: (a) building new irrigation systems along with the improvement of existing ones, (b) land development and agricultural mechanization, (c) integrated crop and water management, and (d) institutional development.

The implementation of this plan is to be supported by the several follow up activities and other relevant national policies. Following is a 10 point recommendation for successful implementation of NIMP

1. **Updating potential sub projects for NIMP**: The long lists of proposed irrigation subprojects for the NIMP are obtained from different sources. The ADB TA 8623 designed questionnaire survey was one such source. The questionnaires were sent to all Gewog through the Engineering Division of the Department of Agriculture. However, only 110 Gewog responded to this questionnaire, which listed 187 new irrigation subprojects. This means that many other subprojects from the remaining Gewog are yet to be identified. It is thus proposed to re-administer the questionnaire survey in the remaining Gewog for collecting and updating the long list of proposed irrigation subprojects

2. **Land pooling for agriculture**: The existing labor intensive farming systems under fragmented small holdings in Bhutan must be addressed to enhance economy of scale in agriculture. Consolidation of agricultural land will allow for greater mechanization and efficient delivery of agricultural inputs. For this, it is proposed that the Ministry of Agriculture and Forest:

    - Field a research study to explore the potential for land pooling in the agriculture sector while preserving the land owners' future security. The study should identify current impediments to land pooling and propose policy and regulatory measures, and incentives to address the constraints

    - Design and implement a pilot project to demonstrate various aspects of land pooling interventions, which may include the following:

        - consolidated land development such as terracing, efficient layout of irrigation canals and farm input infrastructures;

- develop and implement optimum cropping plan through introduction of cropping techniques, labor saving machineries;
- equitable distribution of agricultural production among land owners; and
- product packaging, marketing, and demonstration of benefits of collective approach to farming.

3. **Agricultural support services:** Development of agriculture cannot be prosperous without appropriate agricultural support services. Thus, support in following areas need to be enhanced

    - Agriculture extension services at farm level
    - Access to credit at rural / household level
    - Appropriate subsidies for making agriculture production more attractive to farmers

4. **Public-private partnership / community participation**: There are opportunities of public-private partnership and community participation in the agriculture sector. For this, appropriate policies and activities should be put in place. One such possibility that can be materialized in the near future is public-private partnership in the area of livestock feed production, mainly through the cultivation of irrigated spring maize. Though some dialogue in the area has already been initiated, this needs to be materialized. At present, the entire raw materials for producing livestock feeds are imported from India.

5. **Capacity building**: Capacity of the Department of Agriculture, mainly the irrigation engineering unit (proposed Irrigation and Water Management Section), needs to be enhanced.

6. **Private sector involvement in irrigation development services**: As the Royal Government of Bhutan aims to limit the size of its civil service, the involvement of the private sector in managing agricultural and engineering (irrigation) support services need to be initiated in the country.

7. **Revisit irrigation policy**: Irrigation policy needs to be revisited to address aspects related to: (a) M&E of irrigation development, (b) right of way of canals, (c) community participation and subsidies in irrigation sector, and (d) roles and responsibility of district and central level governments.

8. **Cooperative farming**: Cooperative commercial farming needs to be initiated and promoted. In doing so, irrigation WUA should be regarded as an entry point for services related to irrigated agriculture including agricultural mechanization and marketing

9. **Importing agricultural labor**: The possibility forimporting seasonal agricultural labor from India and Bangladesh to meet peak agricultural labor demands needs to be explored.

10. **Revisit water regulations**: Water regulations need to be revisited to address aspects related to: (a) right of way of canals, (b) categorization of irrigation systems for development planning, and (c) non-resident water users.

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APPENDIX A

Appendix A1: Prioritization of existing canals for modernization

SN	Scheme ID	Gewog	System Name	Areas (ac)		Functional status	Water source	Likely extension		Matching GCA (ac)
				Gross	Net			Potential (GCA-NCA)	Proposed (GCA-NCA > 10 ac)	
1	Bumthang									
1	00101	Chhoekhor	Changwa	60.49	12.45	Functional	Adequat	48.04	48.04	60.49
2	00102	Chhoekhor	Tamzhing	75.44	1.88	Functional	Abundan	73.56	73.56	75.44
3	00105	Chhoekhor	Pangrey	60.92	1.57	Functional	Adequat	59.35	59.35	60.92
4	00318	Tang	Nimlung Gomphu	114.40	9.47	Functional	Adequat	104.93	104.93	114.40
				311.25	25.37				4	
							73.56	Abundant		
							212.32	Adequate		
							285.88	Total	286	311
2	**Chhukha**									
1	00606	Bongo	Bongo	134.18	98.26	Functional	Adequat	35.92	35.92	134.18
2	00702	Chapchha	Ditilum_Arijekha	71.80	28.88	Functional	Abundant	42.92	42.92	71.80
3	00901	Doongna	Mondokha	18.05	6.29	Functional	Abundant	11.76	11.76	18.05
4	00902	Doongna	Choteykha	113.12	50.93	Functional	Abundant	62.19	62.19	113.12
5	00905	Doongna	Rodingkha/	85.83	43.20	Functional	Abundant	42.63	42.63	85.83
6	01001	Getana	Bachu	90.49	80.23	Functional	Adequat	10.26	10.26	90.49
7	01002	Getana	Phusa	41.22	31.06	Functional	Abundant	10.16	10.16	41.22
8	01003	Getana	Tashigang	47.94	32.63	Functional	Abundant	15.31	15.31	47.94
9	01202	Loggchina	Jedokha	28.16	6.51	Functional	Adequat	21.65	21.65	28.16
10	01303	Maedtabkha	Pango	414.17	214.27	Functional	Abundant	199.90	199.90	414.17
11	01402	Phuentshogling	Chomchey	40.38	21.28	Functional	Abundant	19.10	19.10	40.38
12	01404	Phuentshogling	Lingdhen	52.27	30.41	Functional	Abundant	21.86	21.86	52.27
				1138	**644**				12	
							426	Abundant		
							68	Adequate		
							494		**494**	**1138**
3	**Dagana**									
1	01603	Karmaling	Dorjiphu	161.90	42.74	Functional	Abundant	119.16	119.16	161.90
2	01801	Drukjeygang	Pangkaychu_Sertoc	91.43	24.00	Functional	Adequate	67.43	67.43	91.43
3	01802	Drukjeygang	Budichu_Bowgamo	96.17	22.64	Functional	Abundant	73.53	73.53	96.17
4	01805	Drukjeygang	Nachulungpa_Yugse	58.07	14.88	Functional	Abundant	43.19	43.19	58.07
5	01807	Drukjeygang	Tardalum_Albumtah	117.25	16.16	Functional	Adequate	101.09	101.09	117.25
6	01809	Drukjeygang	Yungserbji Irri.	72.16	35.73	Functional	Abundant	36.43	36.43	72.16
7	02003	Gozhi	Gimiri Chhu	165.05	144.78	Functional	Adequate	20.27	20.27	165.05
8	02004	Gozhi	Saureni Channel	40.64	10.54	Functional	Abundant	30.10	30.10	40.64
9	02005	Gozhi	Suberi	67.77	13.86	Functional	Adequate	53.91	53.91	67.77
10	02006	Gozhi	Bublal Kulo	55.04	32.82	Functional	Adequate	22.22	22.22	55.04
11	02007	Gozhi	Karma(ABSDS)	52.72	18.30	Functional	Adequate	34.42	34.42	52.72
12	02010	Gozhi	Sarkar Kulo	121.00	64.05	Functional	Abundant	56.95	56.95	121.00

13	02011	Gozhi	Dungsingma	101.60	37.10	Functional	Adequate	64.50	64.50	101.60
14	02013	Gozhi	Nanduchu Irrigation	165.26	106.84	Functional	Abundant	58.42	58.42	165.26
15	02101	Karna	Didigang channel	59.39	17.28	Functional	Adequate	42.11	42.11	59.39
16	02103	Karna	Okolum	20.38	1.12	Functional	Abundant	19.26	19.26	20.38
17	02104	Karna	Gekolum(Tangchu)	193.40	99.78	Functional	Adequate	93.62	93.62	193.40
18	02106	Karna	Pungshi yuwa	45.33	14.95	Functional	Adequate	30.38	30.38	45.33
19	02112	Karna	Nabray Kholsa	65.12	37.90	Functional	Adequate	27.22	27.22	65.12
20	02114	Karna	Hadolum	158.50	86.48	Functional	Adequate	72.02	72.02	158.50
21	02117	Karna	Gaungang Saiarrey	183.05	87.47	Functional	Adequate	95.58	95.58	183.05
22	02118	Karna	Tangraychu Yuwa	163.00	125.00	Functional	Abundant	38.00	38.00	163.00
23	02119	Karna	Kanakha Bashu	249.00	161.00	Functional	Adequate	88.00	88.00	249.00
24	02205	Khebisa	Akhochen Irrigation	47.07	32.90	Functional	Adequate	14.17	14.17	47.07
25	02302	Largyab	Bana	56.73	43.86	SF	Adequate	12.87	12.87	56.73
26	02303	Largyab	Balung Irrigation	79.98	65.40	Functional	Adequate	14.58	14.58	79.98
27	02401	Lhamoi	Chongsamling	148.80	73.98	Functional	Abundant	74.82	74.82	148.80
28	02405	Lhamoi	Kendrelthang	128.17	77.27	Functional	Abundant	50.90	50.90	128.17
29	02501	Nichula	Bichgoan	94.17	47.39	Functional	Abundant	46.78	46.78	94.17
30	02607	Trashiding	Norbugang	50.30	35.07	Functional	Abundant	15.23	15.23	50.30
31	02609	Trashiding	Tharo	70.87	37.18	Functional	Adequate	33.69	33.69	70.87
32	02613	Trashiding	Balki Khola II	72.05	4.74	Functional	Adequate	67.31	67.31	72.05
33	02615	Trashiding	Kanchaki Kulo	17.45	6.05	Functional	Adequate	11.40	11.40	17.45
34	02623	Trashiding	Gantey Kulo	27.43	5.18	Functional	Adequate	22.25	22.25	27.43
35	02703	Tsangkha	Budhichu_Babaytha	20.43	8.97	Functional	Abundant	11.46	11.46	20.43
36	02706	Tsangkha	Banderchu_peteykh	83.36	29.38	Functional	Adequate	53.98	53.98	83.36
37	02707	Tsangkha	Budhichu_peteykha	247.12	31.89	Functional	Adequate	215.23	215.23	247.12
38	02802	Tsenda-Gang	Darkata/Rithey	309.50	119.30	Functional	Adequate	190.20	190.20	309.50
39	02803	Tsenda-Gang	Dharay Kulo	133.95	40.30	SF	Adequate	93.65	93.65	133.95
40	02804	Tsenda-Gang	Bazaray Kulo	136.00	99.72	Functional	Adequate	36.28	36.28	136.00
				4227	**1974**				**40**	
							674	Abundant		
							1578	Adequate		
							2253	Total	**2253**	**4227**
4	**Gasa**									
1	03003	Khamaed	Zhomina	25.78	13.22	Functional	Abundant	12.56	12.56	25.78
				26	**13**				**1**	
							13	Abundant		
							0	Adequate		
							13	Total	**13**	**26**
5	**Haa**									
1	03501	Gakiling	Ribjee yuwa	73.01	50.73	Functional	Adequate	22.28	22.28	73.01
2	03504	Gakiling	Yongtsena Yuwa	47.60	19.10	Functional	Adequate	28.50	28.50	47.60
3	03803	Sangbay	Gyeldrakha/	33.18	22.69	NF	Adequate	10.49	10.49	33.18
				154	**93**				**3**	
							0	Abundant		
							61	Adequate		
							61	Total	61	154
6	**Lhuentse**									
1	04002	Gangzur	Sharok _A	148.50	40.17	Functional	Abundant	108.33	108.33	148.50
2	04003	Gangzur	Leedong	25.50	7.42	Functional	Abundant	18.08	18.08	25.50
3	04004	Gangzur	Sharok	33.89	23.52	Functional	Adequate	10.37	10.37	33.89
4	04008	Gangzur	Shedombrak	72.76	37.12	Functional	Abundant	35.64	35.64	72.76
5	04009	Gangzur	Chubur	21.92	10.65	Functional	Abundant	11.27	11.27	21.92
6	04010	Gangzur	Manchu	128.46	74.13	Functional	Adequate	54.33	54.33	128.46

7	04011	Gangzur	Tangphey chhu	49.42	25.30	Functional	Abundant	24.12	24.12	49.42
8	04013	Gangzur	Kuendhey me	96.50	71.24	Functional	Adequate	25.26	25.26	96.50
9	04206	Khoma	Zhingeebee	74.96	63.36	Functional	Adequate	11.60	11.60	74.96
10	04302	Kurtoed	Sabragang	195.92	153.63	Functional	Abundant	42.29	42.29	195.92
11	04402	Maenbi	Manjabe yuwa	126.07	112.40	Functional	Adequate	13.67	13.67	126.07
12	04403	Maenbi	Shungkhar Yuwa	153.10	116.10	Functional	Adequate	37.00	37.00	153.10
13	04506	Maedtsho	Tshochen	54.14	22.30	Functional	Abundant	31.84	31.84	54.14
14	04606	Minjey	Ngarchu/sephu	420.76	362.43	Functional	Adequate	58.33	58.33	420.76
15	04607	Minjey	Ngargiang chhu	223.32	200.69	Functional	Abundant	22.63	22.63	223.32
16	04608	Minjey	Dungkhar chhu	322.92	290.20	Functional	Adequate	32.72	32.72	322.92
17	04702	Tsaenkhar	Khepachhu	192.77	113.22	Functional	Adequate	79.55	79.55	192.77
18	04703	Tsaenkhar	Khepachhu	207.15	151.67	Functional	Adequate	55.48	55.48	207.15
				2548	**1876**				18	
							294	Abundant		
							378	Adequate		
							672.51	Total	**673**	**2548**
7	**Monggar**									
1	04901	Chagsakhar	Kharnang	55.06	32.16	Functional	Adequate	22.90	22.90	55.06
2	04902	Chagsakhar	Pam	697.16	145.23	Functional	Abundant	551.93	551.93	697.16
3	05001	Chhaling	Lhakhang	124.77	87.19	Functional	Abundant	37.58	37.58	124.77
4	05007	Chhaling	Khalangzi	65.66	49.46	Functional	Adequate	16.20	16.20	65.66
5	05201	Drepoong	Drepong	70.08	32.98	Functional	Adequate	37.10	37.10	70.08
6	05301	Gongdue	Yangbari(ongoing)	151.50	113.47	Functional	Adequate	38.03	38.03	151.50
7	05902	Saling	Masangdaza	156.94	93.31	Functional	Adequate	63.63	63.63	156.94
8	06004	Shermuhoong	Pempaling	68.29	24.96	Functional	Abundant	43.33	43.33	68.29
9	06005	Shermuhoong	Tsaburi	27.35	7.52	Functional	Abundant	19.83	19.83	27.35
				1417	**586**				9	
							652.67	Abundant		
							177.86	Adequate		
							830.53	Total	**831**	**1417**
8	**Paro**									
1	06703	Doteng	Autsho_Lukhey	115.59	105.52	Functional	Abundant	10.07	10.07	115.59
2	06704	Doteng	Gay chutaka	168.30	94.86	Functional	Adequate	73.44	73.44	168.30
3	06903	Lamgong	Ngamey_Jageithang	175.00	126.60	Functional	Abundant	48.40	48.40	175.00
4	06905	Lamgong	Khamay ekha Nemjo	101.60	62.63	Functional	Adequate	38.97	38.97	101.60
5	06907	Lamgong	Dakaphu_Jagathang	49.79	37.40	Functional	Adequate	12.39	12.39	49.79
6	06911	Lamgong	Bajo_Ngoba	33.28	11.79	Functional	Abundant	21.49	21.49	33.28
7	07006	Loongnyi	RimiY Yeewalkha	42.99	21.46	Functional	Adequate	21.53	21.53	42.99
8	07008	Loongnyi	Guma_Tshapheylo	24.20	11.17	Functional	Adequate	13.03	13.03	24.20
9	07201	Sharpa	Thangyeul	67.10	54.75	Functional	Abundant	12.35	12.35	67.10
10	07202	Sharpa	Zhungkana_Bara	242.50	220.30	Functional	Abundant	22.20	22.20	242.50
11	07303	Tsento	Lomlophu	101.12	56.74	Functional	Adequate	44.38	44.38	101.12
12	07305	Tsento	Tongzhi	223.67	122.39	Functional	Adequate	101.28	101.28	223.67
13	07306	Tsento	Balakha	318.27	130.00	SF	Adequate	188.27	188.27	318.27
14	07404	Wangchang	Jongtoena_chenso	266.30	164.00	Functional	Adequate	102.30	102.30	266.30
15	07406	Wangchang	Kichu Resort_Paro	369.18	348.81	Functional	Abundant	20.37	20.37	369.18
				2299	**1568**				15	
							135	Abundant		
							596	Adequate		
							730	Total	730	2299
9	**Pema Gatshel**									
							0	Abundant		
							0	Adequate		
							0	Total	0	0

10	**Punakha**									
1	08602	Barp	Chugosa Yuwa	83.85	72.45	Functional	Adequate	11.40	11.40	83.85
2	08702	Chhubu	Nidupchu	131.48	98.90	Functional	Adequate	32.58	32.58	131.48
3	08706	Chhubu	Jawakha	139.33	129.31	Functional	Abundant	10.02	10.02	139.33
4	08707	Chhubu	Changchena	79.99	68.05	Functional	Adequate	11.94	11.94	79.99
5	08804	Dzomi	Tana yuwa	166.22	153.34	Functional	Adequate	12.88	12.88	166.22
6	08904	Goenshari	Dochung Shari	145.32	67.81	Functional	Abundant	77.51	77.51	145.32
7	08905	Goenshari	Churukha	142.73	97.49	Functional	Adequate	45.24	45.24	142.73
8	09008	Guma	Okalum	132.29	120.85	Functional	Adequate	11.44	11.44	132.29
9	09106	Kabisa	Betheylum	137.79	116.01	Functional	Adequate	21.78	21.78	137.79
10	09109	Kabisa	Upper Botokha	134.39	121.66	Functional	Abundant	12.73	12.73	134.39
11	09111	Kabisa	Wokatsho	276.97	213.81	Functional	Adequate	63.16	63.16	276.97
12	09209	Lingmukha	Omtekha	217.18	197.36	Functional	Abundant	19.82	19.82	217.18
13	09301	Shenga-Bjemi	Dada yuwa	171.17	160.91	Functional	Adequate	10.26	10.26	171.17
14	09304	Shenga-Bjemi	Gulagang Yuwa	85.91	65.41	Functional	Adequate	20.50	20.50	85.91
15	09305	Shenga-Bjemi	Tangena	38.74	27.95	Functional	Adequate	10.79	10.79	38.74
16	09311	Shenga-Bjemi	Goensa Bja yuwa	173.47	147.97	Functional	Abundant	25.50	25.50	173.47
17	09403	Talog	Begana_Lunakha	351.64	304.52	Functional	Abundant	47.12	47.12	351.64
18	09502	Toedwang	Aum Chungemo	172.64	115.70	Functional	Adequate	56.94	56.94	172.64
19	09505	Toedwang	Yalethang	73.02	51.36	NF	Adequate	21.66	21.66	73.02
20	09510	Toedwang	Thagulum	129.11	115.17	Functional	Adequate	13.94	13.94	129.11
21	09602	Toepisa	Chih yuwa	70.67	56.82	Functional	Abundant	13.85	13.85	70.67
22	09605	Toepisa	Gyentey Yuwa	62.43	34.25	Functional	Abundant	28.18	28.18	62.43
23	09608	Toepisa	Richu	153.53	77.59	Functional	Abundant	75.94	75.94	153.53
24	09609	Toepisa	Byemsae Yuwa	63.94	43.15	Functional	Abundant	20.79	20.79	63.94
25	09611	Toepisa	Eukalum	164.42	142.91	Functional	Adequate	21.51	21.51	164.42
26	09612	Toepisa	Eukana	103.70	81.47	Functional	Adequate	22.23	22.23	103.70
				3602	**2882**				26	
							331.5	Abundant		
							388.3	Adequate		
							719.7	Total	746	3602
11	**Samdrup Jongkhar**									
1	10001	Lauri	Gonoong	57.63	16.27	Functional	Abundant	41.36	41.36	57.63
2	10102	Martshala	Kakpadung/chorten	37.00	25.00	Functional	Adequate	12.00	12.00	37.00
16	10401	Phuntshothang	Belamsharang	73.00	54.00	Functional	Abundant	19.00	19.00	73.00
23	10408	Phuntshothang	Mingigang	49.50	13.82	Functional	Abundant	35.68	35.68	49.50
24	10409	Phuntshothang	Khangmithang	67.00	57.00	Functional	Abundant	10.00	10.00	67.00
26	10411	Phuntshothang	Mingigang/Tikiri	191.00	35.00	Functional	Abundant	156.00	156.00	191.00
28	10413	Phuntshothang	Khathethang	184.10	138.00	Functional	Abundant	46.10	46.10	184.10
31	10417	Phuntshothang	Tsangchhu Thama	71.08	46.00	Functional	Abundant	25.08	25.08	71.08
33	10419	Phuntshothang	Samdrupchholing	74.00	39.00	Functional	Adequate	35.00	35.00	74.00
				804	**424**				**9**	
							333	Abundant		
							47	Adequate		
							380.22	Total	**380**	**804**
12	**Samtse**									
1	10903	Pemaling	Khophi irrigation	43.49	31.06	Functional	Abundant	12.43	12.43	43.49
2	11401	Doomtoed	Thulu	89.15	43.22	Functional	Abundant	45.93	45.93	89.15
13	11501	Namgyelchhoeli	Namgary chholing	277.00	249.97	Functional	Adequate	27.03	27.03	277.00
16	11703	Samtse	Lamitar	65.49	53.72	Functional	Adequate	11.77	11.77	65.49
17	11704	Samtse	Cholicop	159.00		Functional	Adequate	159.00	159.00	159.00
18	11801	Trashichhoeling	Deori kulo	191.30	118.80	Functional	Adequate	72.50	72.50	191.30
19	11802	Trashichhoeling	Sanayanasi	452.60	368.35	Functional	Adequate	84.25	84.25	452.60
21	11804	Trashichhoeling	Labchey_kothigoan	72.47	47.36	Functional	Abundant	25.11	25.11	72.47

22	11805	Trashichhoeling	Bayasi	178.50	156.60	Functional	Abundant	21.90	21.90	178.50
24	12001	Tendruk	Kingaling(pakkhay)	42.86	31.67	Functional	Adequate	11.19	11.19	42.86
25	12002	Tendruk	Kuchintar	176.10	96.42	Functional	Adequate	79.68	79.68	176.10
				1748	**1197**				**11**	
							105	Abundant		
							445	Adequate		
							551	Total	**551**	**1748**
13	**Sarpang**									
1	12308	Samtenling	Limbo kulo	295.00	243.02	Functional	Adequate	51.98	51.98	295.00
2	12404	Chuzanggang	Samdrup	1281.00	1259.0	Functional	Adequate	22.00	22.00	1281.00
3	13112	Sherzhong	Pemaling Irrigation	268.00	239.00	Functional	Adequate	29.00	29.00	268.00
4	13208	Shompangkha	Koaray Kulo	265.00	210.00	NF	Adequate	55.00	55.00	265.00
5	13413	Umling	Lower Dangling	145.00	132.00	Functional	Abundant	13.00	13.00	145.00
				2254	**2083**				5	
							13	Abundant		
							157.98	Adequate		
							170.98	Total	171	2254
14	**Thimphu**									
1	13501	Chang	Depsi Phakha	60.00	14.91	Functional	Abundant	45.09	45.09	60.00
2	13502	Chang	Nagbirong chhu	161.77	26.31	Functional	Abundant	135.46	135.46	161.77
3	13701	Ge-nyen	Tshochekha	26.00		Functional	Abundant	26.00	26.00	26.00
4	13704	Ge-nyen	Geney_Zingkha	118.50		Functional	Adequate	118.50	118.50	118.50
5	13705	Ge-nyen	Zanglekha	53.54		Functional	Adequate	53.54	53.54	53.54
6	13801	Kawang	Chamina_chokor	77.51	25.64	Functional	Abundant	51.87	51.87	77.51
7	14003	Maedwang	Khasakha Yuwa	159.00	47.62	Functional	Abundant	111.38	111.38	159.00
8	14007	Maedwang	Khasadrapchu	53.57	41.38	Functional	Abundant	12.19	12.19	53.57
9	14008	Maedwang	Nyshiphakha	51.20		SF	Adequate	51.20	51.20	51.20
10	14010	Maedwang	Jamda Yuwa	24.23	11.46	Functional	Adequate	12.77	12.77	24.23
11	14014	Maedwang	Pulluna	45.72		Functional	Adequate	45.72	45.72	45.72
12	14015	Maedwang	Tohagoenpa	64.46		Functional	Abundant	64.46	64.46	64.46
13	14016	Maedwang	Silluna	29.14		Functional	Abundant	29.14	29.14	29.14
14	14018	Maedwang	Dhalukha	179.14	30.00	Functional	Abundant	149.14	149.14	179.14
				1104	**197**				14	
							625	Abundant		
							282	Adequate		
							906	Total	906	1104
15	**Trashigang**									
1	14404	Bartsham	Jomori	59.30	45.54	Functional	Adequate	13.76	13.76	59.30
2	14504	Bidoong	Tshekhar Jomo Ri	45.85	27.64	Functional	Abundant	18.21	18.21	45.85
3	14704	Kangpar	Zordung	254.12	189.99	Functional	Adequate	64.13	64.13	254.12
4	15106	Phongmed	Khemary Breng	48.71	22.15	Functional	Adequate	26.56	26.56	48.71
5	15206	Radhi	Orpong	75.39	63.27	Functional	Abundant	12.12	12.12	75.39
				483	**349**				5	
							30	Abundant		
							104	Adequate		
							135	Total	135	483
16	**Trashi Yangtse**									
1	16001	Jamkhar	Khomteng	12.95	2.48	Functional	Adequate	10.47	10.47	12.95
2	16101	Khamdang	Tshotshang	138.91	67.10	Functional	Adequate	71.81	71.81	138.91
3	16202	Ramjar	Wangringmo	125.27	107.51	Functional	Adequate	17.76	17.76	125.27
4	16403	Tongmajangsa	Menchu	306.37	268.67	Functional	Abundant	37.70	37.70	306.37
5	16502	Yalang	Goanpa Lhakhang	62.28	31.27	Functional	Adequate	31.01	31.01	62.28
6	16505	Yalang	yerphey	19.76		Functional	Adequate	19.76	19.76	19.76

7	16507	Yalang	Phuyang	21.30		Functional	Adequate	21.30	21.30	21.30
8	16601	Yangtse	Gangkhar	139.50	33.58	Functional	Abundant	105.92	105.92	139.50
9	16605	Yangtse	Bechen(Lochen)	36.28	7.18	Functional	Abundant	29.10	29.10	36.28
				863	**518**				9	
							172.72	Abundant		
							172.11	Adequate		
							344.83	Total	345	863
17	**Trongsa**									
1	16701	Draagteng	Trashidingkha	72.09	25.63	Functional	Adequate	46.46	46.46	72.09
2	16702	Draagteng	Samcholling	403.77	306.57	Functional	Adequate	97.20	97.20	403.77
3	16703	Draagteng	Changrey	168.08	132.95	NF	Abundant	35.13	35.13	168.08
4	16903	Langthil	Yakhey	92.02	65.57	Functional	Adequate	26.45	26.45	92.02
5	16912	Langthil	Machhu	63.52	44.12	Functional	Adequate	19.40	19.40	63.52
6	17101	Tangsibji	Zalamchu	203.38	178.28	Functional	Adequate	25.10	25.10	203.38
				1003	**753**				6	
							35	Abundant		
							215	Adequate		
							250	Total	250	1003
18	**Tsirang**									
1	17204	Barshong	Sangpang kulo	25.69	9.59	Functional	Adequate	16.10	16.10	25.69
2	17205	Barshong	Garey Khola	29.67	16.26	Functional	Adequate	13.41	13.41	29.67
3	17207	Barshong	Baradurey	36.80	20.61	Functional	Adequate	16.19	16.19	36.80
4	17301	Patshaling	Melay Kulo	78.55	52.29	Functional	Adequate	26.26	26.26	78.55
5	17302	Patshaling	Beteni kulo	100.80	79.46	Functional	Adequate	21.34	21.34	100.80
6	17401	Doonglegang	Dharnal Kulo	51.07	38.21	Functional	Abundant	12.86	12.86	51.07
7	17402	Doonglegang	Achar kulo	38.97	28.47	Functional	Abundant	10.50	10.50	38.97
8	17403	Doonglegang	Mohat Kulo	81.50	42.05	Functional	Adequate	39.45	39.45	81.50
9	17405	Doonglegang	Dulal Kulo	125.10	75.89	Functional	Abundant	49.21	49.21	125.10
10	17406	Doonglegang	Mishra Kulo	72.57	55.67	NF	Adequate	16.90	16.90	72.57
11	17409	Doonglegang	Mandhoj Kulo	119.50	91.38	Functional	Abundant	28.12	28.12	119.50
12	17501	Gosarling	Bhupal kulo	451.21	386.58	Functional	Abundant	64.63	64.63	451.21
13	17502	Gosarling	Bazarey Kulo	260.45	224.59	Functional	Adequate	35.86	35.86	260.45
14	17503	Gosarling	Tamang Kulo	239.24	210.11	Functional	Abundant	29.13	29.13	239.24
15	17504	Gosarling	Bikasey kulo	99.15	83.56	Functional	Abundant	15.59	15.59	99.15
16	17605	Kilkhorthang	Ghimiray Kulo	91.53	80.73	Functional	Adequate	10.80	10.80	91.53
17	17607	Kilkhorthang	Jogi Kulo	125.70	77.75	Functional	Adequate	47.95	47.95	125.70
18	17703	Mendrelgang	Aachaja kulo	75.98	46.60	Functional	Abundant	29.38	29.38	75.98
19	17704	Mendrelgang	Kharka Kulo	89.17	51.65	Functional	Adequate	37.52	37.52	89.17
20	17705	Mendrelgang	Jukey Kulo	29.77	12.60	Functional	Adequate	17.17	17.17	29.77
21	17706	Mendrelgang	Tashipang kulo	30.29	9.52	NF	Abundant	20.77	20.77	30.29
22	17801	Patala	Lower Larey chhu	51.17	24.68	Functional	Adequate	26.49	26.49	51.17
23	17802	Patala	Tharay Kulo	59.03	6.61	Functional	Abundant	52.42	52.42	59.03
24	17804	Patala	Relangthang(Mithun	31.25	15.66	Functional	Abundant	15.59	15.59	31.25
25	17805	Patala	Neycheychhu Kulo	247.70	85.47	Functional	Abundant	162.23	162.23	247.70
26	17903	Phuntenchhu	Sarkharey kulo	88.98	56.25	Functional	Abundant	32.73	32.73	88.98
27	17906	Phuntenchhu	Koiraley kulo	22.79	5.34	Functional	Adequate	17.45	17.45	22.79
28	17907	Phuntenchhu	Cheney kulo	67.24	29.60	Functional	Adequate	37.64	37.64	67.24
29	18001	Rangthangling	Zuelphey goan Kulo	51.93	34.87	Functional	Adequate	17.06	17.06	51.93
30	18102	Shemjong	Mafchan kulo	53.76	35.69	Functional	Adequate	18.07	18.07	53.76
31	18108	Shemjong	Moktan kulo	40.36	18.60	Functional	Adequate	21.76	21.76	40.36
32	18109	Shemjong	Ratish Kulo	77.84	49.33	Functional	Abundant	28.51	28.51	77.84
33	18203	Tsholingkhar	Thingh kulo	157.07	55.46	SF	Adequate	101.61	101.61	157.07
34	18204	Tsholingkhar	Neopaney kulo	33.46	14.32	Functional	Adequate	19.14	19.14	33.46
35	18207	Tsholingkhar	Barakoti kulo	56.76	36.63	Functional	Adequate	20.13	20.13	56.76

36	18208	Tsholingkhar	Kapasay Kulo	29.85	8.50	Functional	Adequate	21.35	21.35	29.85
37	18212	Tsholingkhar	Chettri kulo	38.58	19.24	Functional	Adequate	19.34	19.34	38.58
38	18213	Tsholingkhar	Dhupi kulo	101.30	72.26	Functional	Adequate	29.04	29.04	101.30
39	18214	Tsholingkhar	Naya kulo	49.91	36.86	Functional	Adequate	13.05	13.05	49.91
40	18215	Tsholingkhar	Naya kulo	80.41	56.90	Functional	Abundant	23.51	23.51	80.41
41	18216	Tsholingkhar	Koirala kulo	86.61	57.83	Functional	Adequate	28.78	28.78	86.61
42	18301	Tsirangtoed	Bauri kholsa kulo	16.78	6.22	Functional	Abundant	10.56	10.56	16.78
43	18302	Tsirangtoed	Lower Balu kholsa	109.79	52.48	Functional	Abundant	57.31	57.31	109.79
				3805	**2472**				43	
							440	Abundant		
							690	Adequate		
							1130	Total	1333	3805
19	**Wangdi Phodrang**									
1	18501	Bjednag	Wacheytoe yuwa	110.06	64.60	Functional	Adequate	45.46	45.46	110.06
2	18502	Bjednag	Jangsagang Yuwa	100.29	56.66	SF	Abundant	43.63	43.63	100.29
3	18504	Bjednag	Gongye Yuwa	38.84	25.75	Functional	Adequate	13.09	13.09	38.84
4	18510	Bjednag	Yuwa Tam	43.69	25.22	Functional	Abundant	18.47	18.47	43.69
5	18511	Bjednag	Yuwa Wom	60.32	33.40	Functional	Adequate	26.92	26.92	60.32
6	18516	Bjednag	Wochu	111.60	63.15	Functional	Adequate	48.45	48.45	111.60
7	18522	Bjednag	Key	190.20	101.10	Functional	Abundant	89.10	89.10	190.20
8	18530	Bjednag	Lachu Yuwa	30.78	20.56	Functional	Adequate	10.22	10.22	30.78
9	18531	Bjednag	Zababa	78.48	46.90	Functional	Adequate	31.58	31.58	78.48
10	18535	Bjednag	Tatakha Yuwa	29.70	14.86	Functional	Abundant	14.84	14.84	29.70
11	18601	Darkar	Auchu Sumpa	179.10	100.50	Functional	Adequate	78.60	78.60	179.10
12	18605	Darkar	Patako yuwa	85.77	57.50	Functional	Abundant	28.27	28.27	85.77
13	18606	Darkar	Narechu	49.48	37.95	Functional	Abundant	11.53	11.53	49.48
14	18608	Darkar	Uma Khamey yuwa	227.70	170.00	Functional	Adequate	57.70	57.70	227.70
15	18905	Gase	Pangsho yuwa	249.30	183.40	Functional	Adequate	65.90	65.90	249.30
16	19004	Gase	Lunta Yuwa	72.20	35.23	Functional	Adequate	36.97	36.97	72.20
17	19005	Gase	Mejagu	62.16	38.94	Functional	Adequate	23.22	23.22	62.16
18	19006	Gase	Chukulumchu	30.45	19.17	Functional	Adequate	11.28	11.28	30.45
19	19007	Gase	Hebey	73.80	41.96	Functional	Adequate	31.84	31.84	73.80
20	19201	Nahi	Tashichamulla	122.80	72.79	Functional	Adequate	50.01	50.01	122.80
21	19202	Nahi	Hali Lhading Yuwa	34.27	19.60	Functional	Adequate	14.67	14.67	34.27
22	19203	Nahi	Yusa Wom yuwa	112.50	62.88	Functional	Abundant	49.62	49.62	112.50
23	19205	Nahi	Habasa yuwa	250.30	162.31	Functional	Adequate	87.99	87.99	250.30
24	19603	Ruebisa	Rumina Yuwa	205.40	136.00	Functional	Adequate	69.40	69.40	205.40
25	19604	Ruebisa	Palop Yuwa	81.90	29.19	Functional	Adequate	52.71	52.71	81.90
26	19606	Ruebisa	Jaserkha yuwa	60.29	24.98	Functional	Abundant	35.31	35.31	60.29
27	19607	Ruebisa	Japhu yuwa	112.20	82.87	Functional	Adequate	29.33	29.33	112.20
28	19610	Ruebisa	Ruchikha yuwa	76.40	58.55	Functional	Abundant	17.85	17.85	76.40
29	19801	Thedtsho	Rinchengang yuwa	339.80	195.40	Functional	Adequate	144.40	144.40	339.80
				3220	**1981**				29	
							308.62	Abundant		
							929.74	Adequate		
							1238.36	Total	1238.36	3219.78
20	**Zhemgang**									
1	19901	Bardo	krackpaling	42.69	19.64	Functional	Abundant	23.05	23.05	42.69
2	19902	Bardo	Phulabi	143.90	31.06	Functional	Abundant	112.84	112.84	143.90
3	19903	Bardo	Gongdong machu	49.37	35.85	Functional	Adequate	13.52	13.52	49.37
4	19904	Bardo	Pritigang	134.41	39.79	Functional	Abundant	94.62	94.62	134.41
5	19906	Bardo	Sajenti	141.83	55.47	Functional	Adequate	86.36	86.36	141.83
6	20203	Nangkor	Dakpai	26.12	14.84	Functional	Abundant	11.28	11.28	26.12
7	20208	Nangkor	Buli	67.46	49.21	Functional	Abundant	18.25	18.25	67.46

8	20209	Nangkor	Baipang	40.77	16.43	Functional	Abundant	24.34	24.34	40.77
9	20212	Nangkor	Moidang_Wangdar	92.82	49.27	Functional	Abundant	43.55	43.55	92.82
10	20301	Ngangla	Lhaling	20.29	3.55	Functional	Abundant	16.74	16.74	20.29
11	20305	Ngangla	Low er Sonamthang	75.64	63.21	Functional	Adequate	12.43	12.43	75.64
12	20308	Ngangla	Upper Sonamthang	81.01	64.01	Functional	Adequate	17.00	17.00	81.01
13	20309	Ngangla	Plow gang	55.73	28.03	Functional	Adequate	27.70	27.70	55.73
14	20501	Shingkhar	Thajong	33.43	15.60	Functional	Adequate	17.83	17.83	33.43
15	20502	Shingkhar	Thlay	39.20	25.01	Functional	Adequate	14.19	14.19	39.20
16	20504	Shingkhar	Tlorisa	125.61	57.29	Functional	Adequate	68.32	68.32	125.61
17	20505	Shingkhar	Womling	212.95	122.50	Functional	Adequate	90.45	90.45	212.95
18	20601	Trong	Regang	72.94	26.27	Functional	Adequate	46.67	46.67	72.94
19	20602	Trong	DangKhar	81.18	11.90	Functional	Abundant	69.28	69.28	81.18
20	20605	Trong	Zurphey	59.56	36.25	Functional	Adequate	23.31	23.31	59.56
21	20607	Trong	Andigang	209.80	138.91	Functional	Adequate	70.89	70.89	209.80
				1807	**904**				21	
							414	Abundant		
							489	Adequate		
							903	Total	903	1807

Notes:

	165	Adequate
	115	Abundant

1 NF refers to non functional

2 SF refers to semi functional

3 Balnk in w ater av ailability column indicates that w ater av ailability is either inadequate or acute shortage

4 Scheme ID refers to scheme number of DOA database

Appendix A2: Renovation of existing canals: Long list of irrigation systems identified by 11th FYP

SN	Scheme ID	Dzongkhag	Gewog	Name of Scheme	Command area (ac)	Remarks	NIMP proposed
1		Punakha	Barp	Lobesa	200.0	DRDP	
2		Punakha	Talog	Phenday yuwa	1000.0	Modernization, GOI	
3	08805	Punakha	Dzomi	Jimthang yuwa	604.0		604.0
4	09209	Punakha	Lingmukha	Omtakha Scheme	197.4	Modernization	
5	NI	Punakha	Toepisa	Chuzomsa	130.0		130.0
6	NI	Punakha	Shenga-Bjemi	Domsimo	80.0		80.0
				Dzongkhag (Sub Total)	**2211.3**	**3**	**814.0**
1	18602	Wangdue	Darkar	Mukuchu yuwa	90.0		90.0
2	18701	Wangdue	Dangchhu	Lhachu yuwa	113.0		113.0
3	18902	Wangdue	Gase-tshogom	Gase yuwa	443.0		443.0
4	19106	Wangdue	Kazhi	Dechengoenpa	100.0		100.0
5	19304	Wangdue	Nyishog	Pangkabjiyuwa	207.9		207.9
6	18602	Wangdue	Darkar	Bashey yuwa	90.0		90.0
7	19603	Wangdue	Ruebisa	Ngawang Sechuyuwa	450.0	Modernization	
8	19802	Wangdue	Thedtsho	Baychuyuwa	300.6	GOI	
				Dzongkhag (Sub Total)	**1794.6**	**6**	**1044.0**
1	02203	Dagana	Khebisa	Narikachu to Bagaythang via Thomgang	150.0		150.0
2	02402	Dagana	Lhamoizingkha	Tsainzigosa	70.0		70.0
3	NI	Dagana	Tseza	Kari Lum Irri.Channel	350.0		350.0
4	02804	Dagana	Tsenda-Gang	Suntalay Kulo	72.0	Modernization, ML-nca:99.7 ac	
5	NI	Dagana	Karmaling	Karmaling Lift Irrigation	400.0	New lift ??	
6	01802	Dagana	Drukjeygang	Buddichhu to Thangna and Pangna	200.0	Modernization, ML-nca: 22.6 ac	
7	02707	Dagana	Tsangkha	Budeychu - Tsangkha tar	210.0	Modernization, ML-nca: 31.8 ac	
				Dzongkhag (Sub Total)	**1452.0**	3	570.0
1	NI	Trongsa	Draagteng	Longchu Irrigation	300.0	GOI	
2	16909	Trongsa	Langthil	Yurmungtshangchu	180.0		180.0
				Dzongkhag (Sub Total)	480.0	1	180.0
1	14002+ B662	Thimphu	Maedwang	Pungzi	280.0		280.0
				Dzongkhag (Sub Total)	280.0	**1**	**280.0**
1	12202	Samtse	Yetsholtse	Kuchidinia	962.2	GOI	
2	12204	Samtse	Yetsholtse	Lower Kuchidiania	285.7		285.7
3	12201	Samtse	Yetsholtse	Lamitar	145.8		145.8
4	12101	Samtse	Ugyentse	Thakuri Kholsi	142.8	GOI	
5	11803	Samtse	Tashicholing	Hangay	252.5	GOI	
6	11801	Samtse	Tashicholing	Sipsu Khola(penjorling) - Deori kulo	118.8	Modernization	
7	11802	Samtse	Tashicholing	Lower Balbotey	368.4	Modernization	

SN	Scheme ID	Dzongkhag	Gewog	Name of Scheme	Command area (ac)	Remarks	NIMP proposed
8	11805	Samtse	Tashicholing	Sipsu khola	156.6	Modernization	
9	NI	Samtse	Sangachholing	Depheling Meth Kha	120.0		120.0
10	NI	Samtse	Sangachholing	Tharphu	200.0		200.0
11	11701	Samtse	Samtse	Gambadara	129.0		129.0
12	11702	Samtse	Samtse	Mechitar	246.7		246.7
				Dzongkhag (Sub Total)	**3128.3**	**6**	**1127.1**
1	01001	Chukha	Getana	Bachu	80.2	Modernization	
2	01103	Chukha	Geling	Om chhu	211.8		211.8
3	00803	Chukha	Darla	Sillangsa	82.0	NF	82.0
4	00802	Chukha	Darla	U/L Saurani	86.9		86.9
5	00801	Chukha	Darla	Rinchentse	103.6	Gurng gaun	103.6
6	00604	Chukha	Bongo	Ketokha	77.3	NF	77.3
				Dzongkhag (Sub Total)	**641.9**	**5**	**561.6**
1	12507	Sarpang	Dekiling	Ratay	338.0	NF, ML-NCA: 18.56 ac,	338.0
2	12310	Sarpang	Samtenling	Juprey (Beechh-kulo)	125.0		125.0
3	12311	Sarpang	Samtenling	Juprey (Puchar-kulo)	135.0		135.0
4	12308	Sarpang	Samtenling	Roadline (Limbu-kulo)	80.00	Modernization, ML-NCA: 243 ac	
5	NI	Sarpang	Sershong	Thewar (Sershong canal)	205.0		205.0
6	13202	Sarpang	Shompangkha	Pakhey (Kencholing)	200.0	NF, ML-NCA: 66 ac	200.0
7	13404	Sarpang	Umling	Rejuk	86.0	SF	86.0
				Dzongkhag (Sub Total)	1169.0	6	1089.0
1	NI	Tsirang	Kilkhorthang	Dungkharchoeling	80.0		80.0
2	17706	Tsirang	Mendelgang	Tahispang & Pemashong	66.0	Modernization	
3	NI	Tsirang	Sergithang		100.0		100.0
4	18217	Tsirang	Tshilingkhar	Fetay Canal	73.0		73.0
				Dzongkhag (Sub Total)	319.0	4	253.0
1	18217	Zhemgang	Nangkhor	Tali	80.00	NF	80.00
2	20201	Zhemgang	Phangkhar	Tashiling toe, Tashibi, Salangpong	100.00	NF	100.00
3	20402	Zhemgang	Trong	Takabi	100.00	NF	100.00
				Dzongkhag (Sub Total)	280.00	3	280.00
1	16101	Tashiyangtse	Khamdang	Tshotsang Irri channel	67.1	Modernization	
2	16102	Tashiyangtse	Khamdang	Rabkhar Irri channel	100.0		100.0
3	16304	Tashiyangtse	Toetsho	Kheshingri Irri channel	236.5		236.5
4	16402	Tashiyangtse	Tongmajangsa	Mantichu Irri, channel	129.9		129.9
				Dzongkhag (Sub Total)	533.5	3	466.4
1	'05005	Mongar	Challi	Challi irri channel	220.5		220.5
2	05902	Mongar	Saling	Masangdaza irri channel	93.3	Modernization	

SN	Scheme ID	Dzongkhag	Gewog	Name of Scheme	Command area (ac)	Remarks	NIMP proposed
3	05301	Mongar	Gongdue	Yangbari Irri channel	113.5	Modernization	
				Dzongkhag (Sub Total)	427.2	1	220.5
1	04703	Lhuntse	Tshengkhar	Phawangchu Irrigation channel	151.7	Modernization, GOI	
2	04702	Lhuntse	Tshengkhar	Khepachu Irri. Channel	113.2	Modernization	
3	04403	Lhuntse	Maenbi	Shungkhar Irri. Channel	116.1	Modernization	
4	04404	Lhuntse	Maenbi	Serchu Irri. Channel	315.5		315.5
5	04607	Lhuntse	Minjey	Ngarigang chu Irrigation channel	200.7	Modernization, GOI	
6	04604	Lhuntse	Minjey	Bomatang Irri. Channel	103.6	Modernization	
7	04606	Lhuntse	Minjey	Ngarchu/Serchu Irri channel	362.4	Modernization	
8	04303	Lhuntse	Kurtoed	Reeb Irrigation channel	181.1		181.1
				Dzongkhag (Sub Total)	1544.3	2	496.6
1	10305	Samdrup Jo.	Samdrup Choling	Warrangkhola Irri. channel	107.0		107.0
2	NI	Samdrup Jo	Samrang	Samrang Irri.channel	80.0		80.0
				Dzongkhag (Sub Total)	187.0	2	187.0
1	NI	Pemagatshel	Nanong	Mohannelnphu Irri.	80.0	Gewog no match	80.0
2	08205	Pemagatshel	Nobugang	Satshalo Irri. Channel	81.0	Gewog no match	81.0
3	07602	Pemagatshel	Chokhorling	Bahudar irri.channel	200.0	Gewog no match	200.0
				Dzongkhag (Sub Total)	361.0	3	361.0

Note: NI refers to Not identified

Appendix A3: List of new irrigation systems identified by the community (Source: ADB TA 8623 questionnaire survey)

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
MIDDLE MOUNTAIN													
Bumthang													
1	Chokhor	Thangbi/Goling	Open canal	Shobong	Perennial	2.60	60		60	60			60
2	Chokhor	Khasa	Open canal	Kimbang	Perennial	1.00	30		30	30			30
3	Chokhor	Jalikhar/Gongkhar	Lift	Chamkharchu	Perennial	2.00			2,000		2,000		2000
3							90		2,090	90	2,000	0	2090
Dagana										2	1		3
1	Darona	Nimtola	Piped canal	Zhakrey khola	Perennial	0.70		5	5			5	5
2	Darona	Joharkharka	Piped canal	Kopchey khola	Perennial	2.70		30	30			30	30
3	Drujeygang	Tangna	Additional water	Budichu	Perennial	14.00			80	80			80
4	Geserling	Geserling	Lift	Emiray river	Perennial	1.00			40		40		40
5	Geserling	Phuensumgang	Lift	Phunchey	Perennial	3.00	100		100		100		100
6	Geserling	Samtengang	Lift	Pap khola	Perennial	2.00			50		50		50
7	Geserling	Trashithang	Lift	Devithan & Bulkey	Perennial	5.00			110		110		110
8	Geserling	Tanju	Lift	Tanju	Perennial	2.50			50		50		50
9	Goshi	Lower Goshi	Piped canal	Ghising chhu	Perennial	1.00			58			58	58
10	Kana	Kanakha	Open canal	Tangreychu	Perennial	3.50			135	135			135
11	Kana	Nindukha	Open canal	Wochu	Perennial	3.00			188	188			188
12	Kana	Pungshi	Open canal	Lemochu	Perennial	5.00			691	691			691
13	Kana	Lhaling	Open canal	Lemochu	Perennial	10.00			288	288			288
14	Karmaling	Karmaling	Lift		Perennial	2.00			207		207		207
15	Karmaling	Jamathang	Lift		Perennial	1.60			101		101		101
16	Khebisa	Gangkha	Open canal	Gamana chu	Perennial	1.50			240	240			240
17	Khebisa	Gepsa	Piped canal	Sokenya Lum	Seasonal	1.50			68			68	68
18	Khebisa	Thomgang	Piped canal	Patsha	Seasonal	1.70			72			72	72
19	Lajab	Thasa	Lift	Sunkosh	Perennial	1.00		50	50		50		50
20	Laymoizinkha	Zinkha	Lift	Nartaley	Perennial	1.50		15	15		15		15
21	Laymoizinkha	Hawjori	Lift	Jamuna	Perennial	1.00		20	20		20		20
22	Nichula	Nichula	Lift	Sunkosh	Perennial	1.00		31	31		31		31
23	Nichula	Alley	Lift	Sunkosh	Perennial	0.50		5	5		5		5
24	Nichula	Bichgaon	Lift	Sunkosh	Perennial	0.50		15	15		15		15

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
25	Nichula	Daragaon	Lift	Sunkosh	Perennial	0.50		17	17		17		17
26	Tsankha	Pateykha	Additional water	Budichu	Perennial	13.00		70	70	70			70
27	Tsendagang	Lower Tsendagang	Additional water	Pana khola	Perennial	5.00		25	25	25			25
28	Tseza	Jangsagang	Piped canal	Spring	Perennial	1.00		15	15			15	15
28									**2,776**	**1,717**	**811**	**248**	2776
										8	14	6	28
Tashi Yangtse													0
1	Khamdang	Buying	Open canal	Buying	Perennial	1.50			12	12			12
2	Teodtsho	Gongza	Open canal	Dangmechu	Perennial	4.50			63	63			63
3	Teodtsho	Kheni	Open canal	Wagomchu	Perennial	4.30			50	50			50
4	Teodtsho	Jangphutse	Open canal	Singye dra	Perennial	6.50			80	80			80
4									**205**	**205**			**205**
										4			4
Zhemgang													0
1	Bordo	Bardo	Open canal		Seasonal	4.00			80	80			80
2	Bordo	Sameth	Open canal		Seasonal	3.50			60	60			60
3	Bordo	Jowaling	Open canal		Seasonal	2.00			60	60			60
4	Bordo	Dunglabi	Open canal		Seasonal	5.00			30	30			30
5	Bjoka	Pemgopta	Open canal			1.00			18	18			18
6	Goshing	Chaidra/ Mewangang	Piped canal	Umpang chu	Perennial	5.00			13			13	13
7	Yumdanggan g	Yumdang	Open canal	Spring	Perennial	1.60			55	55			55
8	Singkhar	Radhi	Open canal	Sibjagang and Phendegang	Perennial	5.00		30	30	30			30
9	Singkhar	Zangling	Open canal	Taylang	Perennial	3.00		20	20	20			20
10	Singkhar	Nimshong	Open canal	Oopsingla	Perennial	3.00		40	40	40			40
11	Trong	Gongphu	Open canal		Perennial	2.00				0			0
11									**406**	**393**		**13**	**406**
										10	0	1	11
Punakha													0
1	Dzomi	Changjokha	Lift	Po chhu	Perennial	0.04			160		160		160

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
2	Dzomi	Tsekha	Lift	Po chhu	Perennial	0.04			50		50		50
3	Dzomi	Manichain	Lift	Po chhu	Perennial	0.04			20		20		20
4	Chubu	Jawakha	Open canal	Sewla/Bchoid	Perennial	40.00			45	45			45
5	Chubu	Yebisa	Open canal	Kabisa	Perennial	25.00			80	80			80
6	Toedwang	Thamji	Piped canal	Apikewa	Perennial	4.00		50	50			50	50
7	Toedwang	Thamji	Open canal	Tshachu Gikhuna	Perennial	3.50		40	40	40			40
8	Goenshari	Drechukha	Piped canal	Chuklum	Perennial	1.00		40	40			40	40
9	Shengana	Domsimo	Open canal		Perennial	1.50				0			0
10	Toep	Jalu	Piped canal	Pegatapsa	Perennial	4.00			150			150	150
11	Toep	Lemjakha	Piped canal	Hamdolum	Perennial	3.00			62			62	62
12	Kabjisa	Kabjisa	Piped canal		Perennial	0.60			2			2	2
13	Limbu	Gumkha	Open canal	Sengana	Perennial	13.00		60	60	60			60
13									**759**	**225**	**230**	**304**	**759**
										5	3	5	13
Wangdue													0
1	Phobji	Tawa	Open canal	Nemchgang	Perennial	2.00			25	25			25
2	Phobji	Taplu	Open canal	Chaghing	Perennial	2.00			200	200			200
3	Phobji	Taplu	Open canal	Padadash	Perennial	1.00			200	200			200
4	Phobji	Talochen	Open canal	Talogang	Perennial	2.00			150	150			150
5	Phobji	Khomdro	Open canal	Tooyna	Perennial	2.00			80	80			80
6	Phobji	Khomdro	Open canal	Zhepsi	Perennial	2.00			50	50			50
	Gengteng	Mang	Open canal	Mangchu	Perennial	3.00							
	Gengteng	Eusa	Open canal	Mangchu	Perennial	4.00							
	Gengteng	Jengchey	Open canal	Jangchu yeda	Perennial	2.00							
7	Athang	Rukha	Open canal	Morechu	Perennial	12.00			98	98			98
8	Athang	Kasacheko	Open canal	Tinkuchu	Perennial	5.00			20	20			20
9	Bjena	Thenakhe	Open canal	Spring	Perennial	20.00		300	300	300			300
10	Dakar	Gelekha	Open canal	Zachu	Perennial	14.00			94	94			94
11	Dangchu	Reda	Piped canal	Laptsakha	Perennial	4.00			17			17	17
12	Gashetshogom	Gashetshogom	Open canal	Hingdey La	Perennial	25.00		300	300	300			300
13	Kazhi	Kazhi	Open canal	Baychu	Perennial	9.00			70	70			70

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
14	Nahi	Hali	Open canal	Spring	Perennial	8.00			30	30			30
15	Rubesa	Naychagkha	Lift	Baychu	Perennial	0.30			300		300		300
16	Rubesa	Japhu /Zanda /Samdrup	Open canal	Soreychu/Nere chu	Perennial	20.00			800	800			800
16									**2,734**	**2,417**	**300**	**17**	**2734**
										14	1	1	16
Lhuentse													0
1	Gangzur	Gangzur	Piped canal	Tangfey	Perennial	1.50			25			25	25
2	Gangzur	Thospang	Piped canal	Tsanmagang	Perennial	1.00			30			30	30
	Jarey	No schemes											0
	Khoma	No schemes											0
3	Kurtoed	Jasabi	Lift	Kuri chu	Perennial	1.50			21		21		21
4	Kurtoed	Chakzdom	Lift	Kuri chu	Perennial	1.50			9		9		9
	Menjay	No demand											0
5	Maedtsho	Oongar	Piped canal	River	Perennial	0.50		10	10			10	10
6	Maedtsho	Bamdhir	Open canal	Spring	Perennial	2.00		20	20	20			20
7	Maedtsho	Gorsum	Open canal	Spring	Perennial	2.00		5	5	5			5
8	Maedtsho	Drukla	Open canal	Spring	Perennial	1.00		10	10	10			10
8									**130**	**35**	**30**	**65**	**130**
										3	2	3	8
Chukha													0
1	Metakha	Metakha	Open canal	Shinge lum	Perennial	3.50		32	32	32			32
2	Getana	Nubja	Open canal	River	Perennial	2.50	10		10	10			10
3	Getana	Pangsila	Open canal	River	Perennial	3.00	20		20	20			20
4	Bongo	Mertsimo	Lift	Wangchu	Perennial	5.00		20	20		20		20
5	Darla	Gangnag	Piped canal	Spring	Perennial	4.00			20			20	20
6	Darla	Ahllay	Lift	Wangchu	Perennial	4.00			22		22		22
7	Samphelling	Kothiline	Piped canal	Singay khola	Perennial	22.00			165			165	165
8	Dungna	Bisakha	Piped canal	Stream	Perennial	1.50			25			25	25
9	Logchina	Panji	Piped canal	Stream	Perennial	3.00			29			29	29
9									**343**	**62**	**42**	**239**	**343**
										3	2	4	9

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
Mongar													0
1	Drepong	Zunglen/Drepong	Lift	Spring		2.00	70		70		70		70
2	Narang	Gomchu	Open canal	Kholongchhu	Perennial	7.00		60	60	60			60
3	Saling	Zhugthri	Lift	Morichhu	Perennial	1.00		34	34		34		34
4	Saling	Saling	Lift	Lanmanchhu	Perennial	2.50	40		40		40		40
5	Saling	Kalapang	Lift	Lishiwong	Perennial	2.00	50		50		50		50
6	Saling	Resa	Lift	Tongdrang	Perennial	2.00	50		50		50		50
7	Saling	Gortongla	Open canal	Changkichhu	Perennial	1.50		20	20	20			20
8	Saling	Zemgang	Open canal	Namling	Perennial	25.00			120	120			120
9	Tsamang	Tokari	Open canal	Phaedangchhu/ Maeralungchhu	Perennial	8.00		70	70	70			70
10	Tsamang	Banjair	Piped canal	Phaedangchhu	Perennial	8.00	50		50			50	50
10									**564**	**270**	**244**	**50**	**564**
										4	5	1	10
Trashigang													0
1	Barstham	Mantsang	Open canal	Jomiri	Perennial	3.00			70	70			70
2	Barstham	Kumming	Piped canal	Jakhar Dang	Perennial	3.00			80			80	80
3	Barstham	Yetzem	Piped canal	Chuba…	Perennial	1.20			130			130	130
	Samkhar	Chuthadang	Piped canal	Songthi	Perennial	1.00							0
	Samkhar	Shachapo	Open canal	Hogori	Perennial	0.50							0
4	Udzorong	Bapanu	Piped canal	Spring	Perennial	5.00	20		20			20	20
5	Radhi	Radhi	Piped canal	Spring	Perennial	5.00			200			200	200
6	Songphu	Buna	Lift	River	Perennial	0.50		30	30		30		30
7	Songphu	Buna/Dramang	Lift	River	Perennial	1.50	20		20		20		20
8	Songphu	Changmey/ Yobinang	Piped canal	River	Seasonal	5.00		250	250			250	250
9	Songphu	Changmey/ Yobinang	Open canal	River	Seasonal	6.00	200		200	200			200
10	Songphu	Thungthi	Piped canal	River	Perennial	0.50			20			20	20
10									**1,020**	**270**	**50**	**700**	**1020**
										2	2	6	10
Thimpu													0
1	Chang	Yusiphu	Piped canal	Spring	Perennial	3.20	40		40			40	40

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
2	Kawang	Chokhor	Piped canal	Spring	Perennial	2.00	20		20			20	20
3	Mewang	Bjemina	Open canal	Spring	Perennial	0.40	30		30	30			30
4	Mewang	Bjemina	Piped canal	Spring	Perennial	0.80	35		35			35	35
4									**125**	**30**	**0**	**95**	**125**
										1	0	3	4
Trongsa													0
1	Langthel	Dangdung	Lift/Piped canal	Shumgang	Perennial	5.00			180			180	180
2	Langthel	Wengkhang	Lift/Piped canal	Moyamchhu	Perennial	7.00			150			150	150
3	Korphu	Nimshong	Piped canal	Monmang	Perennial	3.00			15			15	15
4	Dragteng	Yussa	Open canal	Urongphel	Perennial	3.00			40	40			40
5	Dragteng	Bratlen	Open canal	Warangang	Perennial	3.00			30	30			30
6	Dragteng	Changvey	Lift	Mangdechu	Perennial	2.00			35		35		35
7	Tangsibji	Kella	Piped canal	Pepchhu	Perennial	0.50		3	3			3	3
8	Tangsibji	Tangsibji	Piped canal	Zalamchhu	Perennial	1.00		4	4			4	4
9	Nubi	Bjee	Lift	Chamdenggang	Seasonal	0.50		51	51		51		51
10	Nubi	Drenshing	Open canal	Chetaylogang	Seasonal	0.50		30	30	30			30
11	Nubi	Semjee	Lift	Matanchu	Perennial	5.00		32	32		32		32
12	Nubi	Mangdi phu	Open canal		Perennial	0.50		10	10	10			10
13	Nubi	Jongthang	Open canal	Thanbtang chhu	Perennial	0.80		5	5	5			5
14	Nubi	Karchung	Lift	Thishpang chhu	Perennial	0.30		5	5		5		5
14									**590**	**115**	**123**	**352**	**590**
										5	4	5	
130		**TOTAL (Middle mountain)**							**11,742**	**5,829**	**3,830**	**2,083**	
										61	34	35	130
Wet Subtropical Irrigation													
Sarpang													
1	Dekiling	Jigmeling	Lift/OC/PC	Bhur khola	Perennial	7.00		215	215.00	215			215
2	Gelephu	Gelephu	Lift	Maochu	Perennial	3.00		300	300.00		300.00		300
3	Jigmecholing	Saundaley	Piped canal	Sawni/Kapri khola	Perennial	6.00		671	671.00			671.00	671

S.N	Gewog	Chewog/Village	Proposed scheme	Source		Distance from source (km)	Command area (ac)			Area by technology (ac)			
				Name	Type		Kamz	Chuz	Total	Open canal	Lift	Piped canal	Total
4	Taraythang	Pemacholing/Yeozargang/Tashicholing	Lift	Khar khola	Perennial	20.00		100	100.00		100.00		100
5	Taraythang	Pemacholing/Yeozargang/Tashicholing/Dorjitse	Lift	Khar khola	Perennial	20.00		109	109.00		109.00		109
6	Taraythang	Yeozargang/Tashicholing/Dorjitse	Open canal	Singye chu/Dorjitse chu	Perennial	20.00		80	80.00	80			80
6		**Total (Sub tropical)**							1475	295	509	671	1475
										2	3	1	6
136		**Total (middle mountain+ Sub tropical)**							**13217**	**6124**	**4339**	**2754**	**13217**

Open canal: 63
Lift: 37
Pipe canal: 36
TotalL 136

Appendix A3 (continued): Dry lands irrigation development subproject (Source: ADB TA 8623 questionnaire survey)

SN	Gewog	Chewog / Village	Proposed scheme	Source		Distance to source (km)	Area (ac)	Area by technology (ac)		
				Name	Type			D/S	WH	Total
Bumthang										
1	Chokhor	Jalikhar/Gongkhar /Nirbugang	D/S	Chamkharchu / Norbugang	Perennial		500	500		500
1							**500**	**500**	**0**	**500**
							1	1		1
Dagana										
1	Drujeygang	Pangserpo	WH	Rainfall	Seasonal		50		50	
2	Karmaling	Labtshaka	Drip/Sprinkler	Spring	Perennial	2.00	50	50		
3	Tashiding	Norbugang	Drip/Sprinkler	Ampi khola	Seasonal	2.50	3	3		
4	Tashiding	Nish kulo	Drip/Sprinkler	Ampi khola	Seasonal	2.50	3	3		
5	Tashiding	Bajgay	Drip/Sprinkler	Ampi khola	Seasonal	3.00	4	4		
6	Tsankha	Tsankha	WH	Rainfall	Seasonal		50		50	
7	Tsendagang	Norbuzinkha	Reservoir tank	Harkatey	Perennial	3.00	24		24	
8	Tsendagang	Norbuzinkha	WH	Rainfall	Seasonal		12		12	
9	Tsendagang	Upper Gangzor	WH	Rainfall	Seasonal		15		15	
10	Tsendagang	Lower Gangzor	Reservoir tank	Pana khola	Perennial	2.00	35		35	
11	Tseza	Khamay	Reservoir tank	Spring	Perennial	1.00	15		15	
12	Tseza	Kalizinkha	WH	Rainfall	Seasonal	0.30	30		30	
12							**290**	**59**	**231**	290
							12	4	8	12
Wangdi										
1	Nisho	Pachakha	Reservoir tank	Spring		0.50				
2	Nisho	Ganju	WH	Rainfall		1.00				
3	Rubesa	Japhu/	Reservoir tank	Japhulum		3.50	665		665	
4	Saephoog	Nalcha	Drip/Sprinkler	Nalchachu	Perennial	0.50	23	23		
5	Saephoog	Busa	Drip/Sprinkler	Zandeychu	Perennial	0.50	77	77		
6	Saephoog	Rukaji	Drip/Sprinkler	Rukalichu	Perennial	0.50	262	262		
7	Thedtso	Matalegchu	Reservoir tank	Limutechu	Perennial	12.00				
8	Thedtso	Thangu	Reservoir tank	Matalegchu	Seasonal					
8							**1,027**	**362**	**665**	**1,027**
							4	3	1	4
Zhemgang										
1	Bordo	Phulabi	WH	Rainfall			60		60	
2	Trong	Zurphey	WH	Rainfall						
2							**60**	**0**	**60**	**60**
							1		1	1
Punakha										
1	Talog	Gnagthrang	Reservoir tank	Talo lum	Perennial	18.00	85		85	85
2	Talog	Nobgang	WH		Seasonal	7.00	130		130	130
3	Goenshari	Gumgey	WH	Jaryney	Seasonal	1.50				0
4	Toep	Lemjakha	Reservoir tank	Chuchuchabel up	Perennial	3.00	62		62	62
5	Kabjisa	Dokuna	Drip/Sprinkler	Rimchu	Perennial	1.00	50	50		50
6	Kabjisa	Sengang	Drip/Sprinkler	Zoghichu	Perennial	0.10	50	50		50
7	Limbu	Limbukha	Dam		Perennial	5.00	118		118	118
8	Limbu	Limbukha	Dam		Perennial	1.50	80		80	80
9	Limbu	Lumpa	Dam		Seasonal	0.50	25		25	25
10	Limbu	Omtekha	Dam	Limpa	Seasonal	1.00	70		70	70

SN	Gewog	Chewog / Village	Proposed scheme	Source		Distance to source (km)	Area (ac)	Area by technology (ac)		
				Name	Type			D/S	WH	Total
11	Guma	Chanjyul/Thara/Dochokha/Rista	Drip/Sprinkler	Nakulum	Perennial	4.00	1,000	1,000		1,000
12	Guma	Lakhu	Drip/Sprinkler	Damche	Perennial	2.00	100	100		100
13	Guma	Walakha	Drip/Sprinkler	Yuste Yuwa	Perennial	15.00	80	80		80
13							**1,850**	**1,280**	**570**	**1,850**
							12	5	7	12
Chukha										
1	Chapcha	Chapcha	SP/DR	Kaso at Paga	Perennial	3.00	30	30		30
2	Chapcha	Chapcha	SP/DR	Lobneykha	Perennial	7.00	70	70		70
3	Bjabcho	Bjacho	SP/DR	Boshi Dang	Perennial	1.00	10	10		10
4	Bjabcho	Bjacho	SP/DR	Mabari	Perennial	2.00	5	5		5
5	Gelling	Geling	SP/DR	Semi shama	Perennial	6.30	30	30		30
6	Gelling	Geling	SP/DR	Komthang lum	Perennial	2.50	25	25		25
7	Gelling	Geling	SP/DR	Apa lum	Perennial	2.00	50	50		50
8	Bongo	Baikunza	Drip/Sprinkler	Spring	Perennial	5.00	82	82		82
9	Darla	Yagang	WH	River	Seasonal	4.00	30		30	30
10	Phuntsoling	Lingen/adumadu/Chouriden	Reservoir tank	Stream	Seasonal	2.00	200		200	200
10							**532**	**302**	**230**	**532**
							10	8	2	10
Mongar										
1	Drametse	Shaphagma	Reservoir tank		Seasonal	1.50	10		10	10
2	Drepong	Drepong	WH	Rainfall	Seasonal	2.00	60		60	60
3	Saling	Kalapang Gonpa	WH	Rainfall			4		4	4
3							**74**	**0**	**74**	**74**
							3	0	3	3
Trashigang										
1	Barstham	Munkhar	WH	Chukur Ghong	Perennial	1.20	150		150	150
2	Songphu	Gongtsephangma	WH		Seasonal		35		35	35
3	Songphu	Challing	WH		Seasonal	1.50	120		120	120
4	Songphu	Dangrey	WH		Seasonal		40		40	40
5	Mewang	Khasakha	WH	Rainfall	Seasonal		138		138	138
6	Mewang	Wolluna	WH	River	Perennial	1.00	25		25	25
7	Dragteng	Khaboe	Drip/Sprinkler	Zhawtleng	Seasonal	1.00	20	20		20
8	Nubi	Gargar	WH	Khajaling chhu	Seasonal	0.50	10		10	10
8							**538**	**20**	**518**	**538**
							8	1	7	8
57							4,871	2,523	2,348	4,871

51 Total canals **51**

Note: DS refers to Drip / Sprinkler, and WH refers to water harvesting **Drip** **22** 29

Sprinkler **29**

Note: Though the total demand of new irrigation projects was 203, only 187 demands specified irrigation type, village, water source, targeted area coverage.

Appendix A4: Final list of irrigation schemes to executed by DoA Engineering Division in 11FYP

Type: New construction

SN	Dzongkhag	Gewog	Name of Scheme	L(km)	Command area (ac)	District areas (ac)	Funding source	NIMP proposed	
								No	Area (ac)
1	Punakha	Kabisa	Naglachen	3.0	128.8		DRDP-Ongoing		0
2	Punakha	Chhubu	Yebisa and Bali	10.0	275.0		GoI		0
						404		0	**0**
3	Wangdue	Gangtey	Mangchuka	5.5	200.0				200.0
						200		1	**200.0**
4	Bumthang	Chhoekhor Thromde	Chamkharthang	1.1	70.0				70.0
						70		1	**70**
5	Dagana	Karna	Dreychhu	8.0	200.0		GoI		0
6	Dagana	Karna		6.0	85.0				85.0
						285		1	**85.0**
7	Trongsa	Korphu	Creedigang (Cardigang)	5.0	180.0				180.0
						180		1	**180.0**
8	Samtse	Ugyentse	Diana-Ugyentse	25.0	340.0				340.0
9	Samtse	Sangachholing	Lingtey=3km, Hariyakhola=2km	5.0	300.0				300.0
10	Samtse	Norgaygang	Kalikhola-Kamigaon	8.8	600.0				600.0
11	Samtse	Norbugang	Tharaykhola-Bimtar	15.0	450.0				450.0
12	Samtse	Dungtoe	Kunchey Khola to Gairi Gaon	15.0	200.0				200.0
13	Samtse	Dophuchan	Dangdungay-Manigang	20.0	1000.0				1000.0
14	Samtse	Samtse	Khandothang	1.0	500.0				500.0
15	Samtse	Beru	Sipsoo khola-Baraney	10.0	200.0				200.0
						3590		8	**3590.0**
16	Chukha	Getana	Bachu	3.7	60.0				60.0
17	Chukha	Bongo	Chungkha(Yuenengpo)	?	90.0				90.0
18	Chukha	Bongo	Chungkha(Pamikha)	7.0	150.0				150.0
						300		3	300.0
19	Zhemgang	Trong	Trong, Dangkhar, Tingbi, Pam, Krashiply	12.00	178.00				178.0
						178		**1**	178.0
20	Tashiyangtse	Ramjar	Lift Irrigation	0.6	127.0		EU		
21	Tashiyangtse	Yallang	Thargom Irri, channel	8.0			GoI		

22	Tashiyangtse	Yallang	Jamaling Irri, channel	2.5	80.0				80.0
						207		1	80.0
23	Mongar	Chaskhar	Gudari Irri channel	9.0	145.2		GoI		
24	Mongar	Challi	Wangla Irri channel	2.5	87.2				87.2
25	Mongar	Saling	Changchu Irri	5.0	80.0				80.0
						312		2	**167.2**
26	Tashigang	Shongphu	Thunmari Irri. channel	5.0	700.0		GoI		
27	Tashigang	Radhi	Yudiri Irri. Channel	4.5	1252.0		KOICA		
28	Tashigang	Samkhar	Rangshikhar Irri. Channel	4.4	79.6				79.6
29	Tashigang	Phongmay/ Bidung	Yabrang Irri. Channel	10.0	500.0				500.0
						2532		2	**579.6**
30	Lhuntse	Kurtoed	Reeb Irrigation channel	4.1	181.1				181.1
						181		1	**181.1**
31	Samdrup Jon.	Pemathang	Omshari Irri. Channel	6.0	576.0		GoI		
32	Samdrup Jon.	Langchenphu	Langchenphu toe Irri. Channel	6.0	100.0				100.0
33	Samdrup Jon.	Samdrup Choling	Mindrupling Irri.channel	5.0	80.0				80.0
						756		**2**	**180.0**
			Total		**9195**	**9195**			

NIMP proposed (without Samste and Samdrup)	14	2021
NIMP proposed (with Samste and Sandrup)	24	5791
Area under present intervention	9	3404
	33	9195

Appendix A5: FAO studied irrigation systems

S.N	Name of scheme	Gewog	Source	Area (acres)	Canal length (km)	Water availability	Intervention type	Remarks
Sarpang Dzongkhag								
1	Sarpang	Shompankha	Saprpangchhu		15	Insufficient (1700)	New	New intake, new canal, but integrate some existing command areas irrigated by a few seasonal canals
2	Pemacholing	Taraythang	Pemacholing	82	2.28	Just sufficient (200 lps)	New	Abandoned since 1991, so needs new construction; presently water scarce, but new source found one km U/S; limited potential for area extension, seems re-settled area
3	Dangling	Umling	Panchkhola/Taklai	136	1.4	Sufficient	New	Existing canal, source diversification, adequate water, new intake, seems modernization of canal, no information on potential area extension
4	Barshongchu (Kheorkhola)	Sershong	Kheorkhola	609	7	Sufficient	New	Built earlier by the GoI in 1975, remained operational until 1980, river degradation and intake non-functional, some canal structures also damaged, canal seems fairly ok, needs new construction of intake at appropriate location, almost new construction of canals with extension, potential expansion of area (350 acres)
5	Karbithang	Chuzagnag	Karbithang	888	2	Adequate (800 lps)	New	Presently irrigated by seasonal source. Perennial source (Kali Khola) can be tapped, potential expansion of area (740 acres)
6	Aipowali	Bhur	Aipowali	297	2	Sufficient (250 lps)	New	Water diversion problem, intake not functional, it seems some waters diverted during winter using pipes, it seems mostly new construction required, potential extension of area not known, water adequate
7	Serankulo	Bhur	Dechepelri	85	3	Sufficient (100 lps)	New	Existing canal, intake problem, new intake required, potential extension of area (50 areas) that is more than the existing one, so mostly new construction
				2097				

Samdrup-Jonkhar								
1	Khateythang	Phuntsothang	Baranadhi	32	1.72	Sufficient	New	Canal constructed in 1983, functional upto 2003, damaged by flood, additonal cultivated area in higher elevation, needs water lift, presently the area is fallow, potential extension exist, but area not known
2	Gairitar	Pemathang	Warongkhola	2471	4	Sufficient (800 lps)	New	Presently irrigated by 4 existing canals, about 1556 acres, New intake and new canal proposed for extension, parts of areas are irrigated by a couple of seasonal sources, intigrated new system, lomited waters, needs intigration of water sources, Feasibility study completed by DOA, Project cost ??
	Total			2503				

Samtse Dzongkhag								
1	Lower Gatia	Chargary	Gatia khola	499	5	Sufficient (1000 lps)	Major rehab / new for extension	Existing and functional canal, needs rehabilitation, water shortage at tail end, large potential for area extension but extension area not quantified
2	Lengthey	Chargary	Gatia khola u/s	89	2.5	Sufficient (250 lps)	New	Canal not functioning since 2004, 2 land slides, needs new construction, needs new intake
3	Shiv khola Lamatar		Shiv khola	1201	20	Insufficient (840 lps)	New	Breaded river with a tendency of later shifting, one existing canal not functioning, 20 km long new canal proposed
				1789				
	3 Dzongkhag Total			6389				

Appendix A6: Potential sub-projects for irrigating rainfed chuzhibgs
TA8623 identified through the study of GIS maps

S.N	Gewog	Area (ac)	Source river	Remarks
Dzongkhag: Samtse				
1	Bara	371	Jaldhaka	
2	Biru	220	Sipsu Khola	
3	Chargarey	787		Long stretch no particular source
4	Chargarey	478	Gathia Khola	
5	Chargarey	266		
6	Chenmari	841	Dhaina khola	
7	Chenmari	206	Tributary of Dhainachhu	
8	Denchukha	1,816	Sam chhu	
9	Dorokha	1,166	Nam chhu	
10	Namgyecholing	259	Tributary of Jitichhu	
11	Pagli	283	Khanabartichhu/Lapchachhu	
12	Samtse	396	Chamarchi Khola	
13	Samtse	203	Buke chhu	
14	Samtse	207	Sangaychhu/Lapchachhu	
15	Ugentse	295	Dhaina khola	
	Sub Total	7,794		
Dzongkhag: Samdrup Jonkhar				
1	Langchenphu	314	Leshingri/Dhansari	
2	Samrang	201	No name khola exists	
	Total	515		
Dzongkhag: Sarpang				
1	Gelegphu irrigation subproject	1500	Water source: Mau Chhu; Likely components: Diversion weir, gravity canal from the river, gravity irrigation in part of the area, lift irrigation from gravity canal for upper parts of the o;d command area	Gelegphu area, which is the largest flat land in the country, is endowed with two main perennial rivers namely Mau Chhu and Taklai Chhu. People have been utilizing waters from the Takalai Chhu since long. But, Mau Chhu is not utilized. Several opportunities exist in developing irrigation in the area utilizing waters from the Mau Chhu, one of which re-vitalization of the Gelegphu lift irrigation built during 1970s

Note: above list includes potential irrigation subprojects of areas more than 200 acres

APPENDIX B

Appendix B1: Costs for project preparation

Description	Rate	Cost (US$)	Remarks
Irrigation sector institutional study for designing efficient irrigation institutions for implementing NIMP		100,000	
Preparation of irrigation development projects (pre-feasibility to detail design) for 91,000 acres		4,550,000	Roughly 5% of the investment cost (say US$ 50 per acre)
Ground water investigation in the wet subtropical areas	USD	1500000	
Hydrological studies for assessing availability of water resources of an un-gauged watershed	US$	50,000	
Development of guidelines: environmental assessment of irrigation intervention,		50,000	
Updating irrigation inventory and mapping		150,000	
		6,400,000	

Appendix B2: Institutional development and capacity building cost

Activities	Cost US$
Physical facilities (DOA, Districts, WUA)	2,000,000
Setting up a Water Availability and Allocation Database	100,000
Development of Guidelines and Technical Manuals	50,000
Development of M&E and Water Security Indicator System for Irrigation	25,000
Engineering Design and System Modeling Toolkits	100,000
Development of automated web-based irrigation design system	50,000
Development of procedural guidelines and manual for formation of multifunctional WUA	50,000
Establishment of WUA federation	50,000
Development of guidelines for mainstreaming GESI and IEE / EIA development planning	50,000
Development of guidelines for vulnerability assessment of irrigation system due to climate change	50,000
Capacity buildings	
Higher studies for engineering and non-engineering staffs (20 persons) of the Royal Government of Bhutan	1,500,000
Training and observation tours for central, regional and district level professionals staffs of the royal government of Bhutan, and irrigation WUA	1,500,000
Capacity building of private sector for project design and management	100,000
Others	125,000
	5,750,000

Appendix B3: Costs for project implementation support services for irrigation development

Project duration 15 years	
National consultants, average 8 numbers for gross 15 years (net 11 years) at the rate of US$ 200,000 per person per month	2,112,000
Support staffs (25% of national consultants	528000
International consultant 2 persons for 5 months a year for 11 years at the rate of US$ 20,000 per person per month	2200000
Physical facilities, equipments, travels etc (50% of national consultant costs)	1056000
Sub Total	5,896,000
Contingencies including taxes (25% of subtotal)	1474000
Total	7,370,000
	7,400,000

Appendix B4: Unit cost for modernization of existing irrigation systems or canals

a. Unit cost for modernization of community managed irrigation system in Bhutan: Re-engineering

SN	Details of irrigation system	Command area (ac)	Canal length	Project cost (million Nu)		Cost of irrigation dev.	
				Year	Cost	Per acres (NU)	Per km of canal (NU)
1	Construction of Kuchidiana Irrigation Scheme, Yoseltse Gewog, Samtse	1043	6.830	2015	51.640	49,511	7,560,761
2	Construction of Thakuri Dara Irrigation Scheme, Ugyentse Gewog, Samtse	275	1.700	2015	19.639	71,415	11,552,353
3	Construction of Gangatey-Hungay Irrigation Scheme, Tashicholing Gewog, Samtse	270	3.000	2015	20.110	74,481	6,703,333
4	Construction of Ngarigangchhu Irrigation Scheme, Menjey Gewog, Lhuentse	201	6.100	2015	19.607	97,693	3,214,262
5	Rehabilitation of Phawangchu/Domkhar Piped Irrigation Scheme, Tshenkhar Gewog, Lhuentse	487	7.000	2015	38.960	80,000	5,565,714
6	Construction of Gudari Irrigation Scheme, Chaskhar Gewog, Mongar	145	6.000	2015	10.740	73,967	1,790,000
7	Construction of Thragom/Chokpagang Irrigation Scheme, Yallang Gewog, Trashi Yangtse	600	7.000	2015	43.208	72,013	6,172,571
8	Construction of Thunmari/Tunmari Irrigation Scheme, Shongphu Gewog, Trashigang	700	4.800	2015	25.233	36,047	5,256,875
9	Construction of Khandothang Irrigation Scheme, Samtse Gewog, Samtse	100	1.500	2015	4.438	44,380	2,958,667
10	Construction of Ngarchu/Serchu Irrigation Scheme, Minjey Gewog, Lhuentse	362	5.800	2015	25.655	70,792	4,423,276
11	Construction of Kalikhola-Mamigoan Irrigation Scheme, Norgaygang Gewog, Samtse	600	9.020	2015	36.189	60,315	4,012,084
11	Construction of Mantichu/Rabkhar Irrigation Scheme, Tomajangsa Gewog, Trashiyangtse	130	1.200	2015	0.911	7,013	759,167
		4913	59.95			61,469	4,997,422

	Average	409.4333	5.00	Nu	US$	
	Average of wet subtropical irrigation	458			26	
	Cost per acres			**57,699**		
	Average of middle mountain region	2625			164	
	Cost per acres			**62,591**		
b	Average unit cost of modernizing 16 similar canals in Nepal			72,968		Source: B.R.Adhikari (personal communication)
c	Unit cost of irrigation modernization in Afghanistan (2012 rate: US$ 1550 per ha; Present unit cost in terms of Nu/acres: 46,186)			46,186		Source: Helman river basin Master plan, technical report, 2013
	Unit cost of irrigation modernization for NIMP			**60,000**	**Nu /acre**	
				938	**US$ /acre**	
				2,316	**US$ / ha**	

Appendix B5: Unit cost for renovation and bottleneck repair of existing canals

SN	Command areas	Canal length (km)	Renovation cost in Nu (2012)			Bottleneck maintenance cost (Nu) 2012		
			per km of canal	Per system	Per acrea	Rate /km	Cost per system	Cost / acre
1	37	1.5	370,000	555,000	15,000	55,500	83,250	2,250
2	74.1	2.5	370,000	925,000	12,483	55,500	138,750	1,872
3	148	5	370,000	1,850,000	12,500	55,500	277,500	1,875
				Average	**13,328**			1,999
			Present cost (add 20%)		15,993			2,399
				Say	16,000			2,400
		Add 10% for middle mountain region			17600			2,640
				US$ / arce	**275**			41
				US$ / ha	679			102

Source: Source: (JICA, 2012), Volume 3

Appendix B6: Unit cost of subprojects under Dry Land Irrigation Development Project (DLIDP)

Name		Panachu	Dorokha	Baikunza	Yuetama	Monmeggang	Tading
Location / District		Dagana	Samtse	Chukha	Wangdue	Trosnsa	Samtse
Net command area (ha)		34.4	4.8	33	14.5	24.3	24.3
Design discharge (l/s)		4	3	1	6.5		4.5/2.5
Main pipe length (km)		1.40	0.35	1.45	3.60		2.4/1.7
Major crops			Cardamom, veg	Orange	Paddy, maize	Paddy, maize	Cardamom, veg
Structures							
	H/W						
	Intake cum collection chamber	1	2	2	1	canal exist	2
	Storage tank	3	2	1	1	2	2
	Flow regulation chamber	1	2				9
	Valve chamber	3			8	2	3
	B/C						
	HH	45	59	50	9	58	36
Cost of civil works (000 Nu)		1813	2444	1450	2201	1924	4901
Date		Jan-15	Apr-15	Apr-15	Apr-15	Apr-15	Apr-15
Cost per ha (000 Nu/ha)		53	509	44	152	79	202
Cost per ha (000 US$)		0.86	8.35				
Cost per acre (000 US$)		0.35					
Cost per acres (000 Nu)		21	206	18	61	32	82
Average cost per acres (000 Nu)		70					
Average cost per acres (000 US$)		1.095		Note: This relates to cost for supply of water			
Average cost for water use system (say drip, sprinklar, direct application, pipe etc) US$ per acres (000)		23.36	Assumed				
Cost of catchment management (000 US$ per acre)		23.36	Assumed				
		116.79					
	Total (US$ per acre)	**1825**	US$ / acre				
	Say	4507	US$ / ha				

Appendix B7: Unit cost for land development
(Land development mainly refers to terracing of Kamzhing)

Average land slope to be terraced	1:2 (V:H)		
Average terrace width	7	M	
Height to be cut	3.5	M	
With half cut & half fill, height to be cut	1.75	M	
Length of a terrace	100	M	
Assme 60% width to be cut & 40% to be fill, width of landslope to be cut	4.2		
Volume of E/W to be cut	367.5	m3	
Cost per m3 of E/W with excavator (say)	30	Nu	Nepal cost NPR: 41.97 / m3
Terrace to be formed	700	m2	
Cost of E/W	11025	Nu	
Cost of site clearance (LS)	500		
Compaction cost (by excavator) 10% of excavation	1102.5		
Leveling the terrace, stabilizing riser etc all complete (LS)	1750		About 5 person day, @ 350 per day
Total cost	14377.5		
Contingencies (10%)	1437.75		
Total cost	15815.25		For 700 m2
Cost per acre	91412	Nu	
Cost per acre	1428	US$	

Appendix B8: Unit cost of agricultural mechanization

11th FYP target for agricultural mechanization (AM)	Acre	3729
Allocated capital budget (Million Nu)	Nu	340
Cost per acre of AM (11th FYP)	NU	91177
Cost per acre of AM (11th FYP)	US$	1425
Cost per acre of AM (NIMP)	US$	1710
	Say	1700

Appendix B9: Unit cost for developing trail within the irrigated command areas

1 acres	4046	sq.m.	
50 acres	202300	sq.m.	
Considering the command area be rectangular (2:1): (L:W)			
Length	636	M	
Width (top / down)	318	M	
Assuming top down trail in every 250m. Number of trail required	3.54		
Total length of trail	1127.2	M	
	1.1	Km	
Assume cost per km of trail (2.5 m) will be same as the cost of canal			
Cost per km of canal as per JICA study	235000		10000 to 370000 per km
Cost per km of trail (half the cost of canal)	235000		10000 to 370000 per km. As per JICA study
So cost per 1.1 km trial (for 50 acres)	258500		
Cost per acre	5170	Nu/acres	
	81	USD/acre	
Say	100	USD/acre	

Appendix B10: Unit costs for integrated crop and water management

Sector wide approach		US$
Participatory diagnostic learning and action planning (DLAP): 75 to 100 US$ per ha in 2005, average 87 US$ per ha	Per ha	217.5
Demonstration (seed, fertilizers, labor, irrigation etc)		100
Supply of improved seeds, saplings, fertilizers etc on subsidized rates		100
Market promotion		100
Subtotal (US$)	per ha	517.5
Technical assistance and extension services (US$)	per ha	600
Total (US$)	per ha	1118
	per acre	452
Say	per acre	500

Project specific approach: Taklai IS		
Taklai ICWMP includes ICWMP + modernization of distribution. So, it involves two types of costs		
Unit rate for ICWMP	US$	500
Unit rate for distribution system	US$	250
Total		750