Multiple Cropping in Bhutanese Agriculture –Present Status and Opportunities

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Executive Summary

Bhutan is a small mountainous country located in the southern slopes of Eastern Himalayas. The country has a total geographical area of 38,394 Square Kilometers with a population of 745,600 people. It has only 2.93% of cultivated area. Agriculture is the main source livelihood for 69% of the population.Majority of Bhutanese farmers are small holder with an average farm size of 3 acres and practice a self-sustaining subsistence integrated farming systems. Despite its' small size, the agro-ecology is diverse due to the large variation in altitude. In agriculture, there are three key distinct farming systems which are the rice, maize and potato based system. Multiple cropping is a common feature of the small holder Bhutanese farmers. Over the centuries, small holder Bhutanese farmers have innovated and adopted multiple cropping as one of the simple mechanisms to produce more per unit area.

In the current 11th Five Year Plan, the goal of the Ministry of Agriculture and Forest (MoAF) is to achieve a green economic growth, inclusive social development, poverty alleviation and climate smart sustainable management and utilization of natural resources. The domestic production of cereals is only able to meet 64% of the county's total cereals requirement. Since the horizontal expansion of area for agriculture is nearly impossible, crop intensification through different forms multiple cropping is seen as one of the most feasible strategy. There are already different initiatives by the Department of Agriculture (DoA) on crop intensification and increasing the cropping intensity in the rice based system.

Multiple cropping is diverse and integrated, andcould be a very good strategy to transform the subsistence Bhutanese agriculture to an intensive subsistence agriculture system. The practices of

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multiple cropping befit the principles organic agriculture which is currently being prioritized. The opportunities from multiple cropping are thus immense if its potentials could be rightly exploited. The DoA has to , however, ensure the prerequisites for multiple cropping.

1.0 Background

Bhutan is a small landlocked mountainous country located in the southern slopes of Eastern Himalayas. The country lies between latitudes 26°45'N and 28°10'N, and longitudes 88° 45'E and 92°10'E. The country has a total geographical area of 38,394 Square Kilometers with a population of 745,600 people. The forest (tree) cover of the country is about 70.46%, arable land 2.93%, meadow land 4.10%, shrub land 10.43%, snow cover land 7.44% and bare areas 3.20% of the total geographic area (LCAR,2010). Agriculture is the mainstay of the people with an estimated 69% of the population engaged in farming. Rice, maize, wheat, barley, buckwheat and millets are the major cereal crops cultivated in Bhutan and rice is by far the most important and preferred food crop of the Bhutanese. Agriculture is very important tothe Bhutanese economy as it engages over69% of the population directly depending on it for their livelihood(MoAF, 2011). In 2011, agriculturesector accounted for about 17.7% of the total GDP of the country (RNR Statistics, 2012). Majority of the Bhutanese farmers continue to practice self-sustaining, integrated and subsistence agricultural production system with small land holdings where farmers grow a variety of crops under different farming practices and rear livestock to meet their household food security.The average cultivated agriculture land holdings are 3 acres per household (RNR Statistics,2012). The productivity per unit area of major food crops is generally low due to limited uses of external inputs and lack of assured irrigation.

Over the centuries, small holderBhutanese farmershave innovated and adopted multiple croppingas oneof the simple mechanisms to produce more per unit area. It is also a proven coping mechanism for averting risks of crop failures.Bhutanese farmers continue to practice different forms of multiple cropping practices with different combinations of crops. The types of multiple practices are mainly determined by the environment at large, agro-ecology,types of crops, needs of the farmers, and the degree of risk of crop predation by wild animals, market demand and availability of farm labour. The multiple cropping practices are dominated by traditional technologies innovated and selected by farmers through their experiences. There is a very limited research focus on this discipline and modern multiple cropping technologies arelimited to a few major staple crops. Thus

the information on multiple cropping practicesin the country in general isvery scanty. This report has used the review of available literature, field observation and discussion with relevant agencies and individuals to compile and consolidate the status of multiple cropping practices prevalent in the country.

2.0 Major Agro-ecology and Farming Practices

The country is broadly categorized into three climatic zones which are sub-tropical in the southern foothills; temperate in the middle valleys and inner hills; and alpine in the northern mountains. Generally, southern foothills are hot and humid during summer and cool in winter. The middle valleys and inner hills are warm in summer and cold in winter, with a pleasant spring and autumn. The alpine mountains are cold throughout the year with long icy winter conditions where cultivation of crops is very limited. The land use, farming systems, crops cultivated, opportunities and challenges in agriculture are thus predominantly dictated by climate, topography and altitude.For the purpose of agricultural planning, the country is divided into six major agro-ecological zones corresponding with altudinalrange and climatic conditions (Table 1).

Table 1: Major agro-ecological zones of Bhutan

Agro-Ecological Zone	Altitude (meters)	Temperature (degree Celsius)			Rainfall (mm per year)
		Monthly Maximum	Monthly Mean	Annual mean	
Alpine	3,600-4,600	12.0	-0.9	5.5	<650
Cool Temperate	2,600-3,600	22.3	0.1	9.9	650-850
Warm temperate	1800-2600	26.3	0.1	12.5	850-1,200
Dry Sub-Tropical	1200-1800	28.7	3.0	17.2	850-1,200
Humid Sub-Tropical	600-1200	33	4.6	19.5	1,200-2,500
Wet-Subtropical	150-600	34.6	11.6	23.6	2,500-5,500

Source: RNR Research Strategy and Plan Document, MoA, 1992

The alpine zone which covers the northern region is characterized by alpinemeadows and is too high to grow any food crops. In the cool temperate zone, rearing livestock is the most common way of living with some dryland farming. The main crops grown comprise wheat, potato, buckwheat, mustard and barley.The warm temperate zone has moderately warmtemperature exceptduring winter when frost occurs and agriculture is widely practiced in terraced irrigated wetlands and drylands. In

the wetland agricultural areas, rice is the main crop which is rotated with wheat, potato, seasonal fodder and several kinds of vegetables.

The drysubtropical zone is warm with moderate rainfall allowing the cultivation of wider range of crops. Rice, maize, mustard, barley, different types of legumes and vegetables are cultivated. The humid subtropical zone has a relatively higherrainfall and temperature. The main crop cultivated in the terraced irrigated wetland agricultural areas isrice followed by wheat and mustard. Citrus (mandarin orange) plantation in the lower altitude and cardamom in the higher elevations are the main cash crops. In the sloppy dryland agricultural areas, maize, millet, mustard, several types of legumes, gingerand vegetables are the predominant crops. The wet subtropical zone hasagro-ecological conditions that favour intensive subsistence agriculture through different forms of multiple cropping. Rice is the main cropgrown in summer which is rotated with wheat and maize that are grown in winter depending on irrigation.Irrigation sources aremostly rain-fed and dry up during winter months. Largescalewinter cropping although technically feasible is normallynot practiced due to the scarcity of water. In the dryland agricultural areas, maize and different types of millets are the main crops which are rotated with many types of legumes, mustard, niger, millet, tuber crops and vegetables.

3.0 Potential of Multiple Cropping

The country has only 2.93% of cultivated area.The physical expansion of area for agriculture is very limited due to the rugged terrain and limited land. Further, the constitution of the Kingdom of Bhutan mandates to preserve a minimum of 60% of the country's area under forest for all times.Of the total arable area, 89% is under different cereals and the domestic production of cereals is only able to meet 64% of the county's total cereals requirement (RNR Statistic, 2012). The scope for large scale commercialization and farm mechanization is difficult inmost part of the country. Small farm size, poorly developed irrigations systems, remotenessand socio-economic status of the farmers are other constraints. This scenario thus calls for the development of an intensive production system. The goal of the Ministry of Agriculture and Forest (MoAF) for the current 11thFive Year Plan is to achieve a green economic growth, inclusive social development, poverty alleviation and climate smart sustainable management and utilization of natural resources. In order to achieve this goal, production has to be enhanced through the adaptation and adoption of technologies that best suits the Bhutanese agriculture environment. The available options include bestagricultural practices for small holder farmers which can make the most efficient use of land, labour and other resources so that the primary objective of food security can be achieved. Currently substantial area of arable land is left fallow due

to lack of irrigation, damage of crops by wild animals, shortage of farm labour and lack of suitable technologies. Multiple cropping offers theopportunity to develop the subsistence production system to an intensive agriculture systemwhich can help meet the food and nutritional security of the small farmers. The degree of intensification can be achieved through time (sequential cropping) and through the intimacyor combination of species by mixed cropping (Beets, 1982).

Multiple cropping is commonly practiced by the Bhutanese farmers in many different forms such as crop rotation, sequential cropping, mixed and strip cropping and multi-storied cropping. Past studies have estimated that 52% of the area under legumes is intercropped (NSSC, 1999), over 15% of the area under maize is under maize-maize sequential cropping (Shrestra, *et.al*. 2006) and the estimated area under maize-potato intercropping is 35% (Roder,*et. al.* 2008).

The different multiple croppingsystems thathave a huge untapped are described below:

i. **Promotion of an intensive subsistence agriculture system through the optimal use of basic resources**- In a production system where arable land,irrigation, scope for mechanization and terrain is a limiting factor for large commercial farming, multiple cropping offers several options to make the subsistence small holder farming into an intensive market oriented productive agriculture system through the optimal use of basic resources like land, water and solar energy. This could be achieved through the adaptation and adoption of a range of suitable technologies.The four agro-ecological zones namely warm temperate, dry subtropical, humid and wet subtropical zones have the potential for crop intensification through sequential cropping, intercropping and mixed cropping.Most of the arable land is left fallow during winter months by the farmers due to shortages of farm labour, water scarcity, predation by wild animals, drudgery and lack of attractive remuneration. The arable land can be effectively and sustainably utilized for crop production by helping to address the production constraints. Higher cropping intensity and Landuse Equivalent Ratio (LER) could be enhanced through sequential cropping and intercropping respectively. This will allow the intensification of production as well as bring other associated benefits. The maize + soybean intercropping studies have shown a much higher LER ratio as compared to sole cropping of maize or soybeans indicating yield advantage from intercropping.

ii. **Stable supply of Food, Feed and Fodder**–The concept of multiple cropping revolves around increasing production by growing more crops per year in time and space through the effective utilization of solar energy and moisture. For small holder farmers, adoption of suitable multiple cropping practices can bring about stable food supply in critical food deficit period.In order to achieve the objectives of poverty alleviation and food and nutritional security, stable supply of food, animal fed and fodder is essential. This has to be achieved by producing more from a limited arable area. Multiple cropping could help produce required crops in lean food insecure periods, generate cash income of farmers and increasing the productivity of crops and livestock. The practice of sequential cropping of maize prior to rice in the wetlands in humid subtropical zone which supplements food in the seasonal food deficit months of July and August, planting of winter fodder prior to the main crop of rice in the warm temperate zone and mixed cropping of vegetables are clear examples.

iii. **Promotion of Climate Smart and Sustainable Agriculture** - Climate change is already posing formidable challenges to the marginal farmers in the country. The farming communities have been experiencing the impacts of frequent erratic weather patterns on their livelihood assets and food security almost every year.The Renewable Natural Resources (RNR) Sector Adaptation Action Plans (SAPA, 2013) has identified crop yield instability, decreased water availability, loss of soil fertility due to erosion of top soil and runoff and outbreak of new pest and disease as a major consequence of climate change.One of the underlying advantages of multiple cropping is that it contributestowards improving the overall health of an agro-ecosystem. The different forms of multiple cropping helps to protect soil from extreme erosion, improves soil structure, enhances the soil fertility status wherever legume is included, conserves moisture and suppresses pests and pathogens (Powers, L.E and McSorley, R. 1999). It thus enables the practice of sustainable agriculture through the effective and efficient utilization of limited resources. Multiple cropping also serves as a biological insurance during times of crop failures mainly from anomalies in weather. There are traditional multiple cropping technologies well adapted to a locality which could be refined and exploited to adapt against the potential threats of climate change. Such locally adapted technologies will be efficient, acceptable and cost effective mechanisms for a climate smart agriculture.

iv. **Promotion of Sustainable Land Management Technologies-** Bhutanese farmers operate in a fragile environment wheremore than 31% of agriculture land is on slopes greater than 50% slope. In the humid and wet subtropical zones, heavy monsoon downpour falling over a short span of time causes high runoff leading to the loss of fertile top soil. Some mechanisms adopted by farmers are terracing, planting of fodder trees and grasses promoted along sloping farmland as hedges that can also provide animal feed, and minimize sheet erosions. Multiple cropping practices can thus enhance the adoption of sustainable land management technologies as well as promote integrated plant nutrition management system for the marginal farmers who cannot effort expensive external inputs.As more crops are grown in the multiple cropping systemsmore crop residues and organic matter are also added in the soil.The different forms of multiple cropping such as intercropping, strip cropping and sequential cropping contributes to improving soil fertility, reduces soil erosion and runoff.

v. **Promotion of Organic Agriculture**- The principles of organic agriculture and multiple cropping are highly compatible.Majority of the Bhutanese farmers practice an integrated farming systemsand continue to use indigenous and traditional technologies. The use of external inputs such as fertilizers and pesticides are minimum and limited to a few important crops like potato, rice, maize, vegetables and apples.The promotion of the cultural practices like crop rotation, trap crops, intercropping, and use of resistant varieties are recommended asthe basic inputs for promoting organic agriculture in Bhutan (NOP, 2007).To take the advantage of the still largely traditionally and sustainable farming that uses the principles of organic agriculture, the country is advocating organic agriculture in targeted areas. The up scaling of multiple cropping technologies will directly contribute in achieving the objective of promoting organic farming in the country. The National Plant Protection Center (NPPC) has adopted Integrated Pest Management (IPM) as the keylong term strategyto manage agricultural pest and diseases which supports multiple cropping.

vi. **Effective utilization of expensive externals inputs** (fertilizers, pesticides and irrigation water)- Bhutanese farmers in some Dzongkhags (districts)tend to use substantially higher level of external inputs mainly chemical fertilizers on cash crops such as potato, vegetables, plantation crops like apples and rice because they help them earn cash and meet the

household requirement. The crops definitely cannot make the full utilization of the applied nutrients. Planting of a second crop after the main crop can make effective use of the residual nutrients. In sequential cropping systems, the nature of a first crop and the fertilizers used are likely to affect the performance of the second crop. Similarly, the first crop can also have either a beneficial or a detrimental effect on the second crop. The greatest effect is on the availability of nitrogen although it is affected by many other variables. For example potato and fodder crops planted in the warm temperate regions benefits from the residual nutrients from rice and can also use the irrigation developed for rice. Similarly in the potato based systems any winter crop planted after potato can benefit from the residual nutrients.Furthermore, in any form of multiple cropping weed infestation is less as land is cultivated in all the seasons in a year.

vii. **Crop diversification**–Multiple cropping advocates the growing of different crops through intercropping, crop rotation, mixed cropping or sequential cropping. In essence it promotes crop diversification. Crop diversification has several advantages over mono-cropping. The direct benefits of crop diversification are the supply of different crops over time which can improve the food and nutritional security of households, generating cash income from the sale of the different products, improve soil fertility and reduce the incidence of certain pests and diseases. The indirect benefits range from employment opportunities to the farming families, in situ conservation of agro-biodiversity and the effective use of resources. The diversification of maize based system in the eastern Dzongkhags through the introduction of upland rice has improved the household food security and reduced the import of rice (Dorji*et al*, 2012).

viii. **One Geog Three Products-** One of the policy directives of the Ministry of Agricultureand Forest (MoAF) is toachieve foodself-sufficiency and alleviation of povertythrough the strategy of "One Geog Three Products' (OGTP). This literally translates into the large scale production of at least three different renewable natural resources products by farmers in a Geog(Block) which is the lowest administrative unit.Multiple cropping is one of the most potential pathways and means to achieve the OGTPobjective of MoAF.

4.0 Pre-Requisite of Multiple Cropping

According to Willem 1982, multiple cropping represents the concept of maximum crop production per unit of land by growing more within one calendar year, maximizing use of available solar energy and other natural resources. Under the Bhutanese agriculture production systems that are largely dominated by small holders, small farm sizes and diverse agro-ecological zones the prerequisites for multiple cropping practices are quite similar to other parts of the world. Apparently, a few very critical factors both socio-economic and technical are essential pre-requisites for enhancing multiple cropping in Bhutan. These factors are briefly elaborated below;

4.1 Socio-Economic Factors

i. **Enablinglegislations to support multiple cropping**– Multiple cropping involves growing more crops over time and space. The sequential planting of different crops is the most feasible form of multiple cropping under the Bhutanese setting. In most part of the country, after the main crop is harvested farmers tend to leave the land fallow. Many farmers interested to cultivate asucceeding crop after the main crop isoften restricted by the damage from stray domestic animals which most farmers allow free grazing in the fallow land after the crop harvest. Unless a community consensual legislation is enacted, crop intensification through multiple cropping will not succeed. The use of other means of crop protection measures such as fencing and crop guarding are expensive and un-pragmatic.

ii. **Incentives for encouraging multiple cropping**-Although, crop intensification is climatically feasible in the four agro-ecological zones of warm temperate, dry subtropical, humid and wet sub-tropical, farmers are not really keen to undertake large scale cultivation of succeeding crops after the harvest of the main crop.The analysis of this problem has indicated shortage of farm labour, low economic returns from the second crop, drudgery, predation of crops by wild animals and lack of markets have been cited as the key limiting factors. Amongst all, crop predation by wild animals is the most severe and challenging factor. The Department of Agriculture has put forth several attempts for over two decades to encourage spring rice cultivation in Punakha-Wangdi valley in the rice-rice rotation, yet,

there is very little expansion in the area cultivated to spring rice.Different forms of multiple cropping was an established phenomenon in *Tsheri Land* (slash and burn system), however, due to the government legislation on the restriction of *Tsheri*, the practice has declined. Reverting to *Tsheri* is not an option as the potential environmental consequences from slash and burn far outweighs the economic returns. It is therefore imperative to encourage farmers for multiple through different forms of sustainablepositive incentives.Gurung, Dorji and Katwal, (2008), have suggested resettlement of farms nearby forest to safer places through exchange ofland, and the institution of a feasible cost sharing mechanisms for supplying appropriate fencing materials as an immediate measure to reduce crop predation by wild animals for encouraging crop intensification through multiple cropping.

iii. **Creation of market and demand**–Multiple cropping will allow production of crops at different times. The production are ready for the market at the end of the growing season and farmers are often discouraged as they can sale their produce easily or have to travel long distance to market the produce. Due to the perishable nature of the commodities promoted under multiple cropping, farmers easily tend to incur losses. Unless good and well thought out marketing options are not guaranteed to the farmers, they are not ready to buy the idea of any crop intensification schemes. The recent focus on intensification of off season vegetable production and the cultivation of onion and tomato in the wet land prior to rice are classical examples of lack of poor marketing strategies.

iv. **Availability of Farm labour-** Multiple cropping does not allow high degree of mechanization. It rather hinges on the practice of increased cultural practices and intercultural operations. The demand for farm labour is therefore relatively higher as compared to mono cropping. Many households leave their land fallow or grow limited range of crops due toshortage of farm labour. A study on causes of fallowing prime wetland during the main planting season revealed the shortage of farm labour as the predominant and widespread cause across sites with 38% of the respondent raising farmlabour shortage as the main reason (Gurung, Dorji and Katwal, 2008). Regular availability of farm labour is thus an important consideration for the success of multiple cropping.

4.2 Technical Factors

For any form of crop intensification initiatives suitable climatic factors are a perquisite. The prevailing weather conditions, the length of the growing season, the average temperature and rainfall pattern directly influence crop production. The technical factors which form the prerequisites for multiple cropping are:

i. **Suitable Agro-ecology**- The agro-ecology of an area comprises all important biophysical, technical and socioeconomic components of farming systems and hence determines the production opportunities and challenges in agriculture. Favorable agro-climatological factorsdirectly influences time of planting, growing cycles of crop, choice of crops and varieties, important pest and diseases, types of cropping pattern and ultimately the yield. The location of a production area with suitable agro-ecology is equally important for multiple cropping because anything that is surplus has to be marketed. Peri-urban areas have much wider scope of crop intensification due to the ease of marketing the produce.Agro-ecology also provides a general framework for development and evaluation of technology because a technology from a humid subtropical agro-ecology cannot be generally extrapolated to the warm temperate zone.

ii. **Fertility Status of the Agricultural Land**- The status of the soil is the primary factor that supports higher productivity per unit area. Multiple cropping focuses on maximum crop production per unit area through higher cropping intensity and maximization of the use of the agriculture land by growing more crops per unit area and time. Where multiple cropping is to be promoted, the soil has to be fertile, well drained and responsive to inputs so that it can adequately support higher cropping intensity. The field should not be prone to soil erosion, degradation by natural calamities like occasional flood or drought or severely infested with weeds, pests, pathogens and parasites.

iii. **Assured Irrigation**– Irrigation is the most important factor that supports crop production. It is particularly necessary for crops that are to be cultivated in the pre-and post-monsoon period. At present irrigation facilities is least developed and is mainly targeted for rice. Adequate and assured irrigation throughout the cropping season ensures the success of the crop and avoids

crop failures. Farmers are experiencing more erratic weather patterns, particularly the rainfall. It is very important to design and develop suitable types of irrigation facilities that suit the small size and gradient of the farms.

iv. **Availability of Suitable Technologies**- Theagricultural production environment in the country is very diverse and challenging due to the large temporal and spatial variation in climate. The growing seasons, temperature and rainfall widely vary over short distances and within a given locality due to effects of mountains and valleys. In the higher evaluation there is an early initiation of frost and cold temperature reduces the length of growing season while in the lower altitudes hailstorms and drought are more restrictive. There is thus immense challenge to identify suitable technologies which fits well with the growing conditions, farmers needs and that they are economically viable. The use of short duration and versatile crop and crop varieties that can fit into different forms of multiple crops have to be available. The architecture of the crop intended for intercropping with companion crop has to be suitable so that it can adequately use light and solar energy or tolerate shading effects. Appropriate types of tools and implement that will reduce drudgery and support mechanization are equally important.

v. **Suitable Post-harvest and Market Opportunities**–The access to goodpost-harvest technologies and opportunities directly influence the success of multiple cropping. Farmers should be given the assurances that they will not lose their produce by putting in place good marketing options of marketing and post production opportunities. Development of post-harvest technologies is also influenced by multiple factors such as types of crops, location and agro-ecology of place. Improved connectivity to market and a suitable marketing system will encourage farmers to produce more. The large demand for fresh vegetables, easy access to market due increased network of farm roads, reliable means of transportation and high price have encouraged many farmers in the peri-urban areas of the country to go for multiple cropping of vegetables.

5.0 Present Status of Multiple Cropping in Bhutan

Multiple cropping is an age old practice of intensive farming practiced by the Bhutanese farming communities in various forms. As is the case in many South Asian countries where small holder

agriculture is predominant, multiple cropping practicesare widespread in Bhutan. It is more prominent in the dry, humid and wet subtropical agro-ecological zones where higher rainfall, higher temperatures and longer growing seasons prevails favouring continual crop production.Multiple cropping is done in food crops, plantation crops and fodder crops.

5.1 Types of Multiple Cropping

The predominant multiple practices are crop rotation mainly in the form of sequential planting; intercropping, relay cropping, random mixed cropping, line sown mixed cropping, multiple cropping of forage with food and horticulture crops,strip cropping andagro-forestry The typeof multiple cropping practices varies with altitude, agro-ecology and types of crops cultivated across the country. In this report the types of multiple cropping which are very predominant and practiced in large scale are described under each relevant section while those practiced in a smaller scale are summarized in the Table 2.

5.1.1 Crop rotation

This type of multiple cropping is practice in the form of sequential planting of two or more crops in the same field. Different crops are grown in sequence on the same field, with the succeeding crop planted after the preceding crop is harvested. The different crop rotation prevalent in are:

a. **Rice – Rice rotation in the mid altitudes (700-1500 meters above sea level**) - Growing oftwo crops of rice is practiced in the mid altitude rice growing areas where there is assured irrigation.The Dzongkhags where it can be practiced are Wangdue, Punakha, parts of Trashigang and Mongar in the dry subtropical zone. This system is also referred as rice double cropping or spring rice cultivation. The seedlings for the first crop have to be raised under protected conditions (polytunnel or plastic house) in the first week of February and the crop is transplanted in the second week or mid of March. The rice varieties recommended for the first crop are No. 11 and Barketwhile the variety for second crop is IR20913. The nursery for the second crop is seeded in the second fortnight of June and transplanted in the second fortnight of July. Nursery could be raised either by wetbed or semi-drybed methods.The average yield of first crop is estimated at 2.80t/acre. Despite the big demand for rice and support from the

government,rice double cropping is popular only in Thedtsho Geog (Block) under WangdueDzongkhag. Some of the constraints of the farmers are birdattacks;crop maturity coinciding with monsoon making harvest operation very difficult and often delays second the crop, and the rigidity of the system.

b. Rice – Wheat –It is estimated that about 60% of the wheat area in Bhutan is thewheat grown after rice in the wetlands. The wheat cultivated after rice in the rice-wheat system is also known as spring wheat. Three improved varieties namely Sonalika, Bajoka-1 (HD 2380) and Bajoka-2 (BL 1093) isrecommended for this system. The wheat is sown in November after the rice is harvested. Immediately after rice is harvested, fields are ploughed and a well pulverized soil is prepared where wheat seeds are broadcasted. The wheat is harvested in May.

c. Vegetables – Rice- Planting of different vegetables before the main crop of rice is a very popular practice in the warm temperate agro-ecozone. It is widely practiced in the Paro, Wangdi, Punakha Dzongkhags (districts) due to the large demand for vegetables from the urban population. A variety of vegetables mostly chilly, beans, tomatoes, peas, cole crops and potato are cultivated in the wetland before the main crop of rice. Vegetables are planted as a source of cash income. Immediately after the vegetables are harvested, rice is transplanted.

d. Maize – Barley – Planting of barley immediately after the harvest of maize as a short duration catch crop is carried out in the maize production zone II (1200- 1800 masl) and highland maize production Zone (>1800 m asl). Immediately after the harvest of maize in July- August, the fields are ploughed and barley is sown by late August to early September. The barley establishes with the residual moisture and nutrients from the maize field. The moisture requirement of barley is met from the winter frost. The local barleyvariety overwinters and is harvestedin March just before planting maize. Barley is normally used for brewing local drinks (*Ara and Bhangchang*) that are essential for religious, social and cultural ceremonies. At present only two traditional varieties (*Karfemong* and *Kharmafemong*) are available with the farmers. The average grain yield of barely in this system ranges from 0.40 - 0.50 t/acre. The additional advantages of barley are that as a cover crop it helps in conservation of soil by reducing wind erosion, conserves soil moisture by allowing the penetration of winter rainfall and frost into the soil, and provides fodder for animals in winter.

e. **Maize– Maize-** Maize double cropping constitutes about 15% of the national maize area and is widespread in the six eastern Dzongkhags where maize is the staple food. It is practiced in the rainfed dryland and is most prevalent at the altitude range of 600-1500 m asl. The second crop of maize is planted in August and harvested by October-November. The second crop of maize is referred by farmers as *Lok-pa Ashom*in the local dialect.Farmers normally use local short duration variety *Theksumpa* or improved maize variety Yangtsipa for the second crop.The*tengma(*roasted and flattened maize) often loosely referred as cornflake;apopular product prepared from second maize fetches a very high price in the local market.

f. **Maize – Legumes**- Planting of different legumes in rotation with maize is an established practice in the drylands under dryand humid sub-tropical agro-ecozones. A variety of legumes namely Rajma Beans or Kidney Beans (*Phaseolus vulgaris*), Soybeans (*Glycin max)*Urd beans (*Vignamungo*), Peas(*Pisumsativum*), Groundnut (*Arachis hypogea*)and Cowpea (*Vignaunguiculata*) are mono croppedin rotation with maize. The cultivation ranges from 200 to approximately 2700 m asl. Themaize is sown during February-March and harvested in July- August. After maize is harvested legumes are sown in August and harvested by late October to November. These legumes are normally sold in the local markets as cash crops which fetches very good price. The crop residue of the legumes is fed to the cattle as fodder. The additional advantages of legumes come from their nitrogen fixing ability and also as cover crops which reduce soil erosion.

g. **Potato- Mustard**- This system is very popular in high altitudes potato growing Geogs(blocks) of Tang in Bumthang, Samar in Haa, Chapcha in Chukha and Naja in Paro where farmers sow mustard after harvesting potatoes. The main advantage of this system is low labour requirement. The mustard uses the residual nutrients applied for potato. The mustard yield is estimated to range from 160 to 560 Kg/acre (Roder, *et. al.* 2008).

Fig.1. Mustard sown on dryland after potato harvest Source: http://dengkohno.fotki.com/album

h. **Potato- Maize (Fodder)**- Planting of maize for fodder as a typical ley farming after potato in the potato based system is a relatively new form of crop rotation that is gaining popularity in a few Geogs under Paro and Haa Dzongkhags. The potato crop is harvested in July and maize is sown immediately. The fodder maize is harvested in the second week of October before the onset of frost. The maize is dried and preserved as winter silage.

5.1.2Intercropping

Potato + Maize Intercropping -This is the most established kind ofmultiple cropping practiced by the Bhutanese farmers in the maize production zone II (1200- 1800 m asl) and highland maize production zone (above 1800- 2700 m asl) in the rainfed drylands.Potato is an introduced crop in the country and this system of intercropping is fairly new in the Bhutanese agriculture production system. This system has to some extent displaced the traditional maize- beans intercropping. Maize-potato intercropping practice is most popular in the altitude range of 1200- 2400 m and constitutes 35% of the total potato area in the country (Walter, *et al*., 2008). In this system, potato which is the main crop is planted in February in ridges and maize is planted into the furrows between the two ridges in March. Potato is harvested in July and the land is passed on to the maize crop which is harvested by September. According to Walter, *et al*., (2008), the various advantages of this system are:

i. Increased productivity of maize and potato combined- This intercropping system gives a much higher Land Equivalent Ratio (LER). The LER in this system is greater than 1 which indicates intercropping is advantageous when compared with pure stand of single crop
ii. Soil conservation- This cropping system is predominantly followed in the steep drylands which are highly prone to soil erosion and run off. The soil after potato harvest will be loose and prone to erosion. The standing crop of maize reduces the impact of falling rain and runoff effects. In addition, the maize stubbles which are collected and heaped in the field improve the soil physical and biological conditions.

iii. The other advantages of this system are that it reduces risk of crop failure and ensures food security of small holder farmers- During the outbreaks of severe Gray Leaf Spot disease in maize from 2005 to 2007 which nearly wiped out the maize, potato served as a good safety net for the farmers. Farmers can also grow a combination of cash crop and staple food in their small holding.

iv. The main disadvantage of this system is the reduction of both maize and potato yields as compared to the pure stands.

5.1.3 Relay cropping

Maize -Beans Relay Cropping-This is a traditional cropping system developed by the farmers and iswidely practiced across the country where maize is cultivated in the dryland. It is infact the oldest form of multiple cropping. Before the maize is harvested, farmers prepare the fields and plant beans. The key feature of this system is that the tall and robust maize plants are used as the physical support by the beans to complete its life cycle. Beans are planted in August and by the time the beans start to climb the maize, maize cobs are harvested and stalks are left behind for support. Beans fetch a good price as fresh winter vegetables.

Fig. 2. Standing crop of maize ready for relay sowing of beans in Tsirang Dzongkhags

5.1.4 Mixed cropping

Different forms of mixed cropping are practiced by the Bhutanese farmers. The types of mixed cropping are influenced by the type of crops, altitude and season. Mixed crop is most dynamic in vegetables where farmers plant various combinations of crops depending on market demand. Kitchen gardens display the most intensive forms of mixed cropping.

i. **Random mixed cropping-** In this system two or more crops are randomly mixed without following an intentional pattern of sowing. The common examples are random planting of beans in a field of maize, cucurbits in maize and maize intercropped in soybeans.

ii. **Line sown mixed –** Line sown mixed crop is not intentionally designed but **is by default due** to the nature of the crop. In a mixed cropping where Ginger+Maize is planted together, ginger is planted on ridges in line and maize is planted in between the two ridges. Due to ridge planting of ginger, parallel lines are formed and when maize is seed in between it forms a line sowing, although the line are not always straight due to the terrain.

Another mixed line sowing is done in potato + sunflower. In this system, sunfloweris intercropped with potatoes. The potatoes are planted in ridges and form a very distinct line planting. The sunflower seeds are sown in between two ridges in March and harvested in October. This system shows a distinct form of mixed line sowing although; the sowing is not designed intentionally.

5.1.5 Strip cropping

The types of strip cropping practiced by farmers are not intentionally designed but they follow the principles of strip cropping and are by default strip cropping due to the terrain and way the crops are planted.

Chilly- Beans/maize - A modified form of strip cropping innovated by the farmers is practiced in the peri-urban area of Paro and Thimphu Dzongkhags mainly in vegetables.This form of cropping follows the principle of strip cropping but the strip of the companion crop which is maize and climbing beans are not in straight row (Fig. 3). This system makes a very efficient use of the land and also maximizes the income of the farmers from the sale of chilly, maize and beans.

Fig.3. Modified strip cropping of beans (left) and maize with chilly (right) inParo Dzongkhag

Rice- Urd beans – This method of intercropping is wide spread in the humid and subtropical agro-ecozone. The rice is transplanted in the terraced wetland with bunds prepared to hold water. The bunds are effectively used to plant Urd beans after the rice transplanting is over. This is a form of strip cropping by default asit is not designeddeliberately but since the bunds planted to Urd beans run parallel to the rice like a strip, the design is very similar to strip cropping.

5.1.6 Mixed with crop of same canopy size

The mixed cropping involving crops with same canopy are not very common in the Bhutanesefarming system. An example of this system is in wheat/barley +mustard practiced by few farmers in the south and east. The sowing of both the crops is done in November. Mustard is harvested earlier than wheat or barley.This system is more common in forage crops where different grass mixture is sown together.

5.1.7 Mixed with crop of different canopy heights (Seasonal/Annual, Biennial, Perennial, Mixture of perennial, biennial and seasonal crops)

Mixed crop with different canopy heights is common in cereals, permanent orchards and vegetables. The most prominent ones are discussed below:

i. Mixture of Seasonal /Annual Crops of different canopy heights

In the seasonal/annual crops, the mixture of crops with different canopy heights is observed in the following crop combinations.

- Maize + Potato + Beans (Mixed)-Peas/beans. Maize and potato are planted in February and March respectively. After 15 to 20 days interval, beans are planted in the same field. The beans are ready for harvest by May which is harvested and sold in urban markets. The potatoes are harvested in late May to early June. In the standing maize field peas and beans are planted in August. This practice is very popular in Tsirang Dzongkhag.
- Maize + Soybeans – The mixed planting of maize with soybeans is popularly practiced in the eastern region.

- Maize + Finger Millet – It is practiced in southern districts in the dryland, where millet is transplanted in the standing maize crop. It is a also a form of relay cropping.
- Ginger + Maize – It is practiced in rainfed drylands in Southernregion of the country. Ginger is planted is April and maize is sown as intercrop in May in between the rows of ginger.
- Ginger +Dhaincha–Normally the seed production of Dhaincha is done in this system and is common in Sarpang Dzongkhag.
- Potato+ Peas - About 15 % of peas are randomly mixed with potato planted in rows. This practice is common in Chapcha Geog(block) under Chukha Dzongkhag (Roder*etal*., 2008).

ii. Mixture of Perennial and Seasonal Crops

This type of mixed cropping is common in the established fruit orchards. The types of orchard and intercrop are determined by the altitudes. The most common types of mixed cropping of perennial and season crops are:

- **Apple- Potato-** Potato is a major cash crop of the farmers. In the apple dominated areas of Thimphu, Paro and HaaDzongkhag, farmers plant potatoes under the apples. Apple owners also lease out their orchards to part time farmers who dwell around the urban areas for planting potatoes. This has dual advantage for the land owner and the farmers. The orchard owner benefits from the good cultural practices and weed control in apples while the lessee farmer benefits from potato.
- **Apple- Vegetables**– Different vegetables mainly cols crops, garlic, carrot, spring onion, chilly, asparagus, radish, peas are intercropped to maximize the use of space in between the apple trees. It is very common in the peri-urban areas of Paro and Thimphu Dzongkhags.
- **Pear/Persimmon- Vegetables** - Intercropping of different types of vegetables under fruit orchards is a recent phenomenon in the dry-subtropical agro-ecological zones in eastern region. With the government's strong promotional program on horticulture in the eastern region, farmers have taken up development of mixed fruit orchards by planting of pear, peach, plum and persimmon. Under these fruit trees a variety of vegetables like cabbage, cauliflower, broccoli, radish, sag, potato, garlic, eggplant, peas and beans are planted. The

vegetables are produced round the year by choosing the right type of crop for the different seasons. Vegetables are also a very good source of cash income.

- **Mango/Citrus- Maize** - This type of mixed cropping is popular in Eastern Dzongkhags particularly in Mongar and Pemagatshel Dzongkhags. Mango and citrus trees are planted in the dryland and maize is normally sown as an under crop in between the fruit trees. The fruits are sold for cash while maize provides the food for the households.

iii. Mixture of Perennial Crops

- **Apple and Asparagus**- Planting of asparagus for vegetables is a very prominent practice in high altitude areas where there are large apple orchards. Asparagus is a highly sought after vegetable by the urbanites and brings very good income to the farmers.

- **Arecanut- Banana-** In the humid and wet subtropical zones which are suitable arecanut plantation, farmers intercrop bananas with arecanut. The arecanut plants grows tall and a does not affect bananas. This system is practiced by some farmers in SarpangDzongkhag.

- **Mixed fruit orchards**-Mixed fruit orchard is commonly promoted by the horticulture program to diversity fruit production. A popular form of mixed fruits orchard comprise pears, peach, plum and persimmon.

5.1.5 Multiple Cropping in terms of crops

The farming systems practices in the country are also categorized into three distinct systemsin terms of the most dominant food crops cultivated. The three distinct systems are the rice based system, maize based system and potato based system. The types of farming practices and the choice of succeeding crops are thus determined by the main crop. A range of multiple practices are adopted in these three systems. Rice based cropping system is exclusively done in the irrigated terraced wetlands. Maize and potato based systems are primarily practiced in the non-irrigated steep rainfed drylands. Maize and potato based systems are invariably intercropped with different crops. The different multiple cropping practices popular in the rice, maize and potato based systems are summarized in Table 2.

In the high altitude cool temperate areas, long duration winter wheat is an important crop that is rotated with Sweet and Bitter Buckwheat. Wheat is sown in November and harvested in July. After the harvesting of wheat in July buckwheat in sown and harvested in September. In the eastern Dzongkhags planting of groundnut in rotation with buckwheat and beans is gaining popularity particularly in Trashigang, Trashiyangtse and Mongar. Groundnut is sown in March – April and harvested in August-September. When groundnut is harvested early buckwheat and bean is sown immediately.

Table 2. Multiple cropping in relation to major food crop based systems

Categories	Crops	Type of Multiple Cropping	Additional Information
Rice Based System	Rice-Rice	Crop rotation	Practiced in small scale in mid altitudes
	Rice- Wheat	Crop rotation	Widespread in mid and low altitude areas
	Rice- Mustard	Crop rotation	Widespread in mid altitude areas
	Rice- Maize	Crop rotation	Popular in humid and wet subtropical agro-eco-zones
	Rice - Potato	Crop rotation	Popular in warm temperate areas in the irrigated wetland
	Rice -Vegetables	Crop rotation	Popular in warm temperate areas in the irrigated wetland
	Rice- Onion	Crop rotation	Onion is a newly introduce crop in the rice system
	Rice- Early Chilly	Crop rotation	Popular in low altitude areas of Trashiyangtse and Mongar Dzongkhags
	Rice-Dhaincha/Niger	Crop rotation	Popular in wet subtropical areas for greening manuring
Maize Based System	Maize + Potato	Intercropping	
	Maize + Soybeans	Random mixed cropping	Popular in eastern region of the country
	Maize + Millet	Random mixed cropping	Practice sin humid and wet subtropical areas in the dryland
	Maize – Soybeans	Crop rotation	Practiced in areas at 1200-1800 m asl
	Maize- Legumes	Crop rotation	Rajma beans, Urd beans, Cowpea, Peas are common
	Maize - Mustard	Crop rotation	Done is small scale
	Maize – Upland rice	Crop rotation	Popular in parts of Pemagatshel and parts of Samdrupjongkhar. Maize is planted in January and upland rice is sown in June after harvesting maize. Rice is ready for the blessed rainy day (*Thri festival)*
	Maize- Buckwheat	Crop rotation	Practiced in dry and humid subtropical zone sin dryland
	Maize- Barley+Mustard	Random mixed cropping	Green mustard plants are fed to animals during winter
	Maize + Ginger	Line Sown Mixed	Popular in dry and humid subtropical areas
	Maize + Vegetables	Random mixed cropping	Mainly cucurbits and beans are planted
	Maize + Tuber crops	Mixed	Popular in humid and wet subtropical agro-eco-zones

Potato Based System	Potato + Maize	Intercropping	Major forms of cropping system in east
	Potato- Mustard	Crop rotation	Popular in high altitude areas
	Potato- Turnips	Crop rotation	Popular in high altitude areas
	Potato- Barley/Wheat	Crop rotation	Popular in high altitude areas
	Potato- Buckwheat	Crop rotation	Popular in high altitude areas
	Potato-Buckwheat-Wheat	Crop rotation	Practiced in drylands in Paro and Haa Dzongkhag
	Potato-Maize (Fodder)	Crop rotation	Practiced in drylands in Paro and Haa Dzongkhags

5.1.6 Multiple cropping in relation to ForageCrops

Ensuring adequate quantityand quality of fodder is one of the many strategies adopted to enhancelivestock productivity in the country. Farmers grow different grasses, legumes, cereals and fodder trees that fits well in their farming system. Ley farming where fodder is produced in the arable land is practiced in some areas although incorporation of grass ley into a rotation is not a normal Bhutanese practice (NSSC, 1999).The popular forage multiple cropping practices prevalent in the country are briefly described below.

i. **Rice – Oat** - Depending on the altitude Oat (*Avena sativa*) is commonly sown as fodder in rotation with rice. In the warm temperate zone Oat is sown in November and December after harvesting rice. In some areas above 2600 m asl sowing is also done in April. Oat is harvested in January to March in the subtropical zone whereas in the warm temperate zone it is harvested from March to June before transplanting of rice.

ii. **Rice- Maize (for fodder)-** This a common practice in the sub-tropical areas where farmers plant a limited area to maize exclusively for fodder for the peak rice transplanting season. Maize is sown with a much higher seed rate to maintain a high plant density in the wetland during May-earlyJune. During the peak planting season when fodder is scarce, the tender maize is harvested and fed to animals particularly to the draught bullocks and milch cows. Recently fodder maize ley farming is gaining popularity is peri–urban areas of Thimphu and Paro Dzongkhags.

iii. **Potato-Turnip**- Turnip is a traditional crop usually cultivated in the higher elevations above 1800 meters. Planting of turnips for fodder after harvesting potato in dryland is commonly

practiced in high altitude potato growing areas. After harvesting of potatoes, seeds of turnips are immediately sown and covered by soil. The turnips are used as winter fodder. The turnips produce fresh yields of 1-2 t/acre. The fresh leaves of leaves of turnips are used as fresh vegetables and are also dried for off season vegetable which iscooked with pork or beef as a delicacy.

iv. **Willow and White clover mixed planting**- In the temperate zone planting of fodder Willow trees (*Salix babylonica*) around the permanent pasture of White Clover (*Trifoliumrepens*) is a common practice in high altitude Dzongkhags (districts) particularly in Bumthang and Haawhere livestock rearing is important. It is an agroforestry system that integrates livestock which is a source of food and farm yard manure. Willow trees are planted along the field border for winter fodder and which also serves as a live fence. It also provides fuel wood and fencing poles. Willow trees are planted about 15-20% of the size of the area of white clover. The white clover fields are used as pasture for grazing cattle during April to September.

v. **Fodder trees intercropped in agriculture land**- It is specific intercropping system and anotherform of agroforestry which combines fodder trees, crops and animals. It is dominant in southern Dzongkhags where different types of fodder trees are planted along the bordersof the cultivated land and degraded areas.The most commonly planted fodder trees are different *Ficus species*, fodder banana, broom grass (*Thysanolaena maxima)*including many other species

vi. **Mixed Fodder under Apple Orchards**- Under sowing of mixtures of fodder species (grasses and legumes) in the apple orchards is a popular form of multiple cropping in the warm temperate agro-ecozone of Thimphu, Paro, Haa and BumthangDzonkhags. The fodder mixture comprise white clover, cocksfoot (*Dactylisglomerata*), Tall fescue(*Festucaarunid-nacea*) and Italian Rye grass (*Loliummultiflorum*). This form of multiple cropping suppressesweeds in the orchard besides supplementing fodder requirements. The fodder crops give a good soil cover in the steep slopes, reduce soil erosion and improvethe overall health of the agro-ecosystem. The cover crops conserve soil moisture through better penetration of rainfall that occurs in the form of frost and snow, improves soil fertility as legume is one of

the components of the cover crops and reduces wind erosion which is quite frequent and damaging during the winter season.

vii. **Perennial Mixed Pasture in Subtropical Zone**- Perennial pastures with mixed grasses are established in the subtropical zone in marginal land and in orange orchards. The grass species used in this type of mixed pastures are Ruzi grass (*Brachiariaruziziensis*), Molasses grass (*Melinismnutiflora*) and Stylo (*Styloanthesguianensis*).

5.1.7 Multiple cropping in terms of irrigation systems

Majority of the Bhutanese farmers almost entirely depend on the seasonal monsoon for most of theirirrigation needs. The irrigated land in the country is less than 18 % of the total arable land and it is mostly focused on rice cultivation (Bhutan Climate Summit, 2011). Dryland agriculture constitutes 61% of the total arable land cultivated which in entirely dependent on seasonal monsoon for irrigation. Irrigation is mainly based on water tapped from streams through locally dugearthen channels and improved reinforce concrete channels. In Bhutan irrigation is normally developed for rice. In vegetables, use of piped water and use of sprinklers is becoming popular. Based on irrigation system, the following multiple cropping is practiced.

i. **Irrigated areas** – In the irrigated wetland,rice– rice rotation practiced in the mid altitudesuse flood irrigation.Other multiple cropping systems involving Vegetables–Rice in wetland, Cereals-Mixed vegetables and Vegetables intercropped in orchards inthe dryland use sprinkler irrigation with piped water.

ii. **Rain-fed areas (Low, Medium, High rainfall)-**All forms of multiple cropping summarized in Table 2 above under the maize and potato based systems are entirely rainfed. Apart from vegetables cultivated under different multiplecropping practices, no other crops in the dryland are irrigated.

5.1.8 Multiple cropping in different soil types/ areas

There are no distinct multiple cropping practicesacross the country that can be clearly categorized by soil types.

6.0 Soil Fertility Management of Multiple Cropping

Bhutanese farmers in general practice a wide range of indigenous and improved soil fertility management technologies that range from tethering cattle, burning of plant debris, application of chemical fertilizers, application of Farm Yard Manure (FYM), green maturing with legumes, leaf litter, intercropping of legumes and terracing (NSSC, 2011). The application of chemical fertilizers is confined to important cereals and cash crops like rice, maize, potato and vegetables. There are no distinct soil fertility management practicesrecommended for multiple cropping systems as farmers generally allocate organic and inorganic fertilizers based on Landuse types and crops to be cultivated.

In the eastern part of the country more FYM is applied on the dryland where maize and potato are the main crops, conversely, in the western part the wetlands receive bulk of the FYM where rice is the main crop; while in the south the farmers generally tether cattle on both wetland and dryland. Generally, farmers do not apply manures and fertilizers to the succeeding crops that follow the main crop. In the maize based system where potato and maize are intercropped, farmers top dress the maize crop after the harvest of potato.

In the ley system prevalent in the irrigatedwetlands in the warm temperate zone where Oat (*Avena sativa*) is planted as winter fodder after rice, farmers give top dressing of nitrogen after the first cutting of the Oat. In the humid subtropical zone,in situ green manuring by planting *Dhaincha* (*Sesbenia aculeate*) is practiced where it is rotatedwith rice and incorporated in the soil by ploughing before flowering prior to the transplanting of rice. In the peri-urban areas where multiple cropping of vegetables is done for market, farmers apply substantial quantities of inorganic fertilizers in the form of Urea and Suphala. Thus soil fertility management in the intensive multiple cropping system still remains an area of investigation.

The National Soil Service Centre (NSSC) leads and coordinates all the programs related to soil fertility, sustainable land management and also provides diagnostic and analytical services related to soil nutrient.

7.0 Plant Protection Aspects of Multiple Cropping

The National Plant Protection Centre (NPPC) under the Department of Agriculture hasthe national mandate to oversee and coordinate thenational plant protection programs. The NPPC advocates the principles of IntegratedPest Management (IPM) as a key long term strategyto manage agricultural pest, disease and weeds. Generally, the use of pesticides in farming is insignificant owing to the factors such as limited access and availability, remoteness of farming communities and strong regulations to avoid the discriminate use. The package of practices for management of pest of diseases majority of the crops strongly emphasizes crop rotations, planting of disease tolerant crop varieties,improved crop husbandry practices, farmer's indigenous pest control practices and intercultural operations which are in line with the concept of multiple cropping. It has been established that farmers traditional practice of continuously mono cropping a single crop leads to the buildup of pest and disease pressure. In the maize based system, continuous cultivation of maize has led to the outbreak of new fungal disease Gray Leaf Spot (GLS) that caused huge economic losses. The most sustainable option recommended to manage GLS is through the planting of disease tolerant maize varieties and field rotation of maize with upland rice, legumes and vegetables (Katwal, *et. al, 2008).*With the recent focus on organic agriculture, different type of bio pesticidesand bio formulations are also evaluated and recommended to the farmers.

Except in rice and potato, no chemicalweed control measures are used for crops. Metribuzin (Sencor 70 WP) is the only chemical recommended for weed control in the potato and maize based farming system. It can also be used under the maize +potato intercropping system.

8.0 Microbiological Aspects of Multiple Cropping

The National Soil Service Center (NSSC) under the Department of Agriculture is institutionally mandated on all microbial aspects of farming. The Soil Microbiology Unit under the NSSC produces and supplies the Rhizobial inoculants for fodder and cultivated species of legumes. The report on the National Legume Survey (1999) indicates that the lack of effective nodulation is not a potential constraint in legumes grown across the country under different cropping systems. The inclusion of

legumes in a cropping system is strongly emphasized and legume cultivation is gaining popularity due to increasing demand and attractive prices. The cultivation of legumes is primarily confined in the dryland farming in the form of intercropping, crop rotation and mixed cropping. A wide range of fodder legumes are also cultivated as covercrops under the like orchards.At the moment, the information available, research and development programs on the microbial aspects on multiple cropping in the country are very limited.

9.0 New Frontiers in Multiple Cropping

Different forms of multiple cropping are increasingly becoming popular with the Bhutanese farmers as a means to make the subsistence agriculture more commercial and market driven. The Department of Agriculture strongly advocates and supports the pursuance of different forms of multiple cropping as one of the primary means to achieve food and nutritional security. The support is provided in the form of free seeds and seedling, support to market the commodities, irrigation and technical advisory services. New forms of multiple cropping, new combinations of crops and higher degree of cropping intensity is found in peri-urban agriculture and is mainly driven by profit. Some of the new frontiers in multiple cropping are organic agriculture, peri-urban and urban agriculture in the form of backyard kitchen and nutritional gardens, herb gardens of medicinal plants and edible landscaping.

9.1 Organic Agriculture-Thegovernment has a long term vision to make Bhutanese agriculture fully organic and has accorded a high priority towards the development of organic agriculture. The formulation of a National Organic Framework was started in 2002 and the policy was officially announced in 2007 (Duba, *et, al*. 2008).The National Organic Program (NOP) of the DoA is mandated to coordinate all the organic programs of the MOAF. The Bhutanese traditional farming practicesare by default largely organic due to the insignificant use of external inputs, remoteness of the farming areas, affordability and limited access to external inputs. Organic agriculture is seen as a potential opportunity to transform the subsistence small holder farming into commercial small holder agriculture by growing high value organic crops under the clean and pristine environment. As the principles of organic agriculture and multiple cropping are highly complementary, focus on organic agriculture is a new frontier and initiative to enhance multiple cropping.

9.2 **Urban and Peri- Urban Agriculture**–The peri urban agriculture is apparently most dynamic, innovative, intensive,and diverse and is becoming highly popular. The agriculture lands are relatively small yet they are intensively cropped with a cropping intensity over 300% in some farms. All forms of multiple cropping such as mixed cropping, strip cropping, multi-storyed cropping and crop rotations are practiced.These are also the most diverse farms as they are planted with a variety of crops mainly the vegetables. This driving factors for intensive multiple cropping can be attributed to the high demand from the urban dwellers, assured weekend markets, attractive prices, easy access to seeds and new technologies and higher degree of awareness of the farmers.

In the urban areas, small stretches of vacant land and alleys between the structures are gainfully used in the form of backyard kitchen garden. Backyard farming is popular with the Bhutanese urbanites and where they plant various crop mixtures mostly vegetables. The National Organic Program has initiated compost making with biodegradable kitchen wastes engaging urban housewives to support backyard urban farming in Thimphu city. The urban dwellers flock the streets during the evenings and weekends to sell their surplus vegetables.

9.3 **Edible Landscaping**– This form of agriculture is seen amongst a few urbanites. It may not be consciously designed but some agriculture enthusiast's plant ornamental crops mainly flowers mixed with a few fruitplants and vegetables to develop a multi-functional edible landscapes. With education and higher level of awareness on nutritional requirements, edible landscaping is gaining popularity although there are no programs designated to support and promote these form of agriculture. In the edible landscaping, few fruits tree mainly apples, peach, pear, plum, walnut and persimmons are planted along with all kinds ofseasonal vegetables, leafy greens, climbers and different perennial and seasonal flowers. Flower pots, poly pots and empty cans are also used for planting flowers and vegetables. One big advantage of edible landscape is that it provides fresh food that

Fig.4. Edible Landscaping in urban areas

can be consumed immediately after harvest.

10.0 Social and Economic Factors, Contribution to Rural Livelihood Development, Food and Nutritional Security Roles of Multiple Cropping

As has been already discussedin the preceding sections, majority of the Bhutanese farmers are subsistence smallholders who farm on small land holdings with very little use of external inputs. The rugged terrain and remoteness impose tremendous challenges for farm mechanization and commercialization of agriculture. Although the agriculture export is dominated by the horticulture crops, fruit crops in particular are hardly irrigated.The physical signs of climate change such as erratic rainfall patterns, frequent incidents of flash flood, droughts and insurgences of new pests and diseases are proliferating. It has been established that poverty in Bhutan is mostly a rural phenomenon. The Poverty Analysis Report (PAR), 2012 has estimated that 12 percent of thepopulation is found to be poor and live below the total poverty line at Nu. 1,704.84 per person per month.In the back drop of this setting, multiple cropping helps accomplish the social and economic needs of the Bhutanese farmers contributing to the improvement of rural livelihood, food and nutritional security. The social and economic benefits of multiple cropping in the Bhutanese context are evident from the following.

i. Multiple cropping makes small Bhutanese farms more diverse and sustainable as it focuses on effective and efficient use of available resources. It avoids dependence on a single crop. It serves as bio insurance and a safety net for poor farmers who can fall back on another crop if one fails. Vegetables which are cultivated in rotation with cereals and intercropped with fruits serve as source of cash income.

ii. A more diverse farmhelps farmers meet their subsistence, social and cultural needs besides the *in-situ* conservation of agro-biodiversity resources. During the agro-biodiversity fairs for farmers conducted by the National Biodiversity Center (NBC), some farmers have displayed upto48 different varieties of cereals, legumes and vegetablewhich are maintained to meet their subsistence, social and cultural needs (Katwal*et al.*2011).

iii. Multiple cropping systems are more resilient to climate change because they are diverse, sustainable as they use less external inputs,and also make efficient uses of resources. It also

helps farmers to cope during crop failures as a result of emerging pest problems. A good example in place is the recommendation of crop rotation (maize-upland rice, maize-vegetables) in a continuous maize based system after the 2007 Gray Leaf Spot (GLS) epidemic in the maize growing areas in eastern region that has helped to reduce GLS incidence and complimented farmers household food security.Similarly roots and tuber crops like sweet potato, yams and tapioca grown as mixed crops with maize supplements food security of the households. Mixed cropping of soybeans and beans with maize enhances the nitrogen status of the soil.

iv. The harvest in a multiple cropping system is spread over the season addressing the issue of seasonal food shortages. Bhutanese farmers face seasonal food shortages in the periods of intensive agriculture operations which are mainly in summer months. The practice of growing maize in the wetland before the main crop of rice helps farmers in subtropical agro-ecozone to overcome acute food shortage during the peak rice transplanting season.

v. Multiple cropping is a source of employments in peri-urban areas where there is a higher unemployment pressure. Youth, normally school students during the school breaksare attracted to work due to higher wage rates.

vi. The country has a negative balance of trade on cereals, edible oils and horticultural commodities. These commodities are all imported from India and have contributed substantially to the shortage of Indian Rupees in the country. Multiple cropping is one of the strategies pursued by the government to upscale domestic food production and reduce the imports. It is also astrategic measure adopted to reduce the shortage of Indian Rupees.

vii. The promotion of mixed vegetable gardens among farmers and schools by the Department of Agriculture and School Agriculture Program has become an important source of nutritional requirement of the children. Intensive multiple cropping of vegetables havealso become a reliable source of cash income for the Bhutanese farmers.

11.0 Existing Programs, Approaches to Promote Multiple Cropping

The DOA under the MoAFis the apex organization that plans, coordinates and approves all the relevant programsand projects on agriculture.The Directorate of the DoA has three functional divisions namely Agriculture, Horticulture and Engineering. The National Organic Program which is relatively new is linked and subsumed under Agriculture Division. All the planned research and development programs are implemented through the networks of institutions and the National Extension System which is decentralized to the Dzongkhags (districts) and Geogs (blocks).

The DOAhas different strategic technical institutionsthat specializes on particular subject andis mandated to lead in its assigned discipline. The National Plant Protection Centre (NPPC) based at Semtokha is mandated to provide IPM services and the National Soil Service Centre (NSSC),is the lead agency for all servicesrelated to sustainable land management, diagnostic and analytical services related to soil nutrient. The Agriculture Machinery Centre (AMC) at Paro has the national mandate of farm mechanization**.** The National Seed Center (NSC) takes care of all aspects of seed and seedling supply. The Food Cooperation of Bhutan (FCB) and the Department of Agricultural Marketing and Cooperatives facilitate the marketing and trading of agriculture commodities. The departmental programs include technical support by the central agencies to the Dzongkhag and Geog programs. The field programs are planned and implemented by the technical staff posted in Dzongkhags (districts) and Geogs (blocks).

There are three Regional Research and Development Centers (RNR RDCs) which are strategically located at Bajo, Wengkhar and Bhur. The RNR RDC at Bajo located in the West Central region leads and coordinates the National Field Crops program; the RNR RDC at Wengkhar, based in the East coordinates the national horticulture research programs whilethe RNR RDC at Bhurhas the responsibility to coordinate research and development programson other cereals and legumes including sub-tropical rice. These three RNR RDCs further operate and extend their services through their sub centers and Dzongkhags Extension services.

The Council of RNR Research of Bhutan (CoRRB) is the apex authority for all RNR related researches which are conducted by different departments namely, Agriculture, Livestock, Forest and

Park Services, and Department of Agriculture Marketing. The School Agriculture Program under CoRRB supports and promotes agriculture among youth is schools. The College of Natural Resources (CNR) a tertiary institute under the Royal University of Bhutan teaches agricultural science as a professional degree course. The Rural Development Technical Center (RDTC) under the MOAF imparts skills on agriculture as a vocation and enterprise to the interested youth, agricultural entrepreneurs and farmers.

In the current 11 FYP, the DOA will be implementing three programs that aim to ensure food and nutritional security and increase income through improved management of field crops, horticulture crops and medicinal plants, and development of agricultural infrastructure. In the arable agriculture the two key programs of the DOA are the National Field Crops Commodity Development Program and the National Horticulture Commodity Development Program. The strategies under the commodity developmentare holistically designed to cover all aspects of the commodity which include research and development, irrigation, plant protection, soil fertility, management practices, commercialization, intensification and multiple cropping. The strategies and approaches to promote and support multiple cropping are encompassed within the commodity development programs. The commodities under the national field crop commodity development program are rice, maize, oilseeds, other cereals (wheat, barley, millet, buckwheat) and Grain legumes. The national horticulture commodity development program in the 11 FYP comprises vegetable development program, citrus development program, potato development program, fruits and nuts development program, spices, medicinal and aromatic plants program, and mushroom development program. Apart from the field crops and horticulture commodity development programs, the National Organic Program (NOP) willsupport agriculture commodity specific organic farming.

To give an immediate start to crop intensification in the 11 FYP, the MoAF has prioritized the scaling up of winter cropping through multiple cropping by bringing the land usually left fallow in the winter months. In the current autumn season, sequential planting of maize, wheat, oilseeds, fodder and vegetables will be promoted through supply of free seeds and other technical inputs across the country.

12.0 Conclusion

Bhutan is primarily an agrarian country with 69% of the population dependent on agriculture for their livelihood. The rugged and challenging physio-geographic conditions coupled with limited arable land are the key limiting factors for modernization of agriculture through farm mechanization, development of irrigation and commercial farming. Meeting food self-sufficiency and poverty alleviation continues to remain one of the key challenges of the government. Currently, nearlyhalf of the cerealsrequirement of the country is met through imports which have resulted in the negative balance of trade and shortfall of Indian Rupees as most of the goods and service are imported from India.

The Department of Agriculture under the Ministry of Agriculture and Forest is exploiting several techniques to enhance food production. Recently, the government has been emphasizing on increasing cropping intensity through multiple cropping, as one of the means to accelerate food production. Given the nature of farming practices which are mostly subsistence, small farm size and focus on sustainable agriculture such as organic agriculture; multiple cropping can beeffective and efficient technique.Multiple cropping refers to growing more than one crop on the same field during the season. Multiple cropping makes effective use of inputs such as soil, water, fertilizer and labour while the output per unit area increases by manifolds. Multiple cropping is diverse and integrated, and thus suitable for subsistence small holders as it can be practiced in annual food crops, fodders, vegetables, fruit plants and perennial crops. If adequately promoted and the current constraints of the farmers are addressed, it could enable the country to be self-sufficient in food production.

13.0 Reference

BEETS, W. C. 1982. Multiple cropping and tropical farming systems, Gower Publishing Co.

DORJI, L., GURUNG, T. R., KATWAL, T. B. & DORJI, D. K. 2008. Study of fallow wetlands in eastern Bhutan: An analysis of the causes of fallowing and suggestions for prevention and enhancing rice production in the region. *RNR RC Wengkhar Technical Document No 40 /Res Com / 2008.* RNR RC Wengkhar: Council for RNR Research of Bhutan.Ministry of Agriculture.

DORJI, L., KATWAL, T. B., WANGDI, N., ADHIKARI, N. B., CHONEY, R. & WANGCHUK. D. 2012. Upland rice a potential option to increase rice Production in Bhutan, A review of research and development interventions. RNR Research and Development Center, Wengkhar, Mongar.

DUBA, S., GURUNG, T. R. & GHIMIRAY, M. 2008. Promoting Organic Farming in Bhutan: A Review of Policy, Implementation and Constraints. Council for RNR Research of Bhutan.Ministry of Agriculture.

KATWAL, T. B., ADHIKARI, N. B., DORJI, L. & WANGDI, S. 2008. Economically Important disease of Maize Prevalent in the High and Mid altitudes Areas of Bhutan. *In:* CORRB (ed.). Mongar: RNR RC Wengkhar.

KATWAL, T. B., GHIMIRAY, M. & DORJI, S. 2011. Conservation, Development and Sustainable Use of Crop Genetic Resources for Livelihood and Food Security in Bhutan. Ministry of Agriculture and Forests. Thimphu, Bhutan.

LCAR. 2010. Land Cover Assessment Report. *In:* AGRICULTURE (ed.). Thimphu, Bhutan: The National Soil Service Center and the Policy and Planning Division.

MOAF. 2011. The Draft 11th Five Year Plan *In:* AGRICULTURE (ed.). Thimphu: Policy & Planning Division, Ministry of Agriculture & Forests.

MOAF. 2012. Bhutan RNR Statistics. 2012. *In:* DRUKPA, K. (ed.). Thimphu: Policy & Planning Division, Ministry of Agriculture & Forests.

NOP. 2007. A Guide to Organic Agriculture in Bhutan. National Organic Program. Thimphu: National Organic Program.

NSB. 2004. The Poverty Analysis Report, 2004. Thimphu: The National Statistical Bureau.

NSSC. 1999. Report on the National Legume Survey. National report prepared by the Sustainable Soil Fertility and Plant Nutrient Management Project Office Thimphu: National Soil Service Center (NSSC).

NSSC. 2011. Indigenous Technical Knowledge on Soil and Soil Fertility Management. Thimphu: National Soil Services Center (NSSC).

PAR. 2012. Poverty Analysis Report. National Bureau of Statistics. Royal Government of Bhutan.

POWERS, L.E & MCSORLEY, R. 1999.Ecological Principles of Agriculture.Delmar.Thomson Learning.Delmar, 3 Columbia Circle, PO Box 15015, Albany, NY 12212-0515.

RGOB. 2011. Climate Summit for a Living Himalayas. Bhutan 2011. *In:* AGRICULTURE (ed.) *Impacts of Climate Change on Food Security* Thimphu: Department of Agriculture.

SAPA. 2013. The Sector Adaptation Plan of Action (SAPA) for the Renewable Natural Resources Sector, Second Draft, April 2013 *In:* AGRICULTURE (ed.). Thimphu: The Council of RNR Research of Bhutan.

SHRESTHA, S., KATWAL. T.B. & GHALLEY, B. B. 2006. Adoption and Impact Assessment of Improved Maize Technologies in Bhutan. RNR RDC Wengkhar: Council of RNR Research of Bhutan.