4. GROW

Living off the land

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Glossary

Agroecological/agroclimatic zones
Agroclimatic and agroecological zones are regions with similar climate, rainfall, soil types, topography, vegetation, and water resources. An overview of the zones provides a holistic view of ecological characteristics and their relation to agricultural practices.

Transhumant pastoral
Transhumance[2] is the regular movement of herds among fixed points in order to exploit the seasonal availability of pastures. Transhumant pastoralists often have a permanent homestead and base where crops are grown for home consumption. Older members of the community remain here throughout the year. A characteristic feature of transhumance is herd splitting; the herders take most of the animals to search for grazing but leave the resident community with a nucleus of lactating females.

Agropastoral
Agropastoralists[3] can be described as settled pastoralists who cultivate sufficient areas to feed their families from their own crop production. While livestock is still valued property, their herds are smaller, possibly because they no longer rely solely on livestock and depend on a finite grazing area which can be reached from their villages within a day. Agropastoralists invest more in housing and other local infrastructure and, if their herds become large, they often send them away with more nomadic pastoralists.

Agroforestry pastoral mixed production systems
This system typically incorporates different resources through cropping, livestock raising and forestry and gets established over a long period of time.

Crop-based livestock production[4]
Farmers keep only enough livestock that can be fed on crop residues and by-products, especially in spring and winter.

Shifting cultivation[5]
Shifting or *jhum* cultivation is a form of agriculture, in which an area of ground is cleared of vegetation and cultivated for a few years and then fallowed for regeneration until its fertility has been naturally restored. Shifting cultivation is an age-old practice that occupies a distinct place in tribal agriculture and its economy, constituting a vital part of the socio-economic framework of tribal life.

Terraced agriculture
Terraced agriculture can be rain-fed or irrigated and is usually found on slopes which are more than 30 percent. Terraced fields decrease erosion and surface runoff and are effective for growing crops requiring much water, such as rice. Terraces are made by levelling land on the hill slopes and in many places occur as a result of many years of cultivation.

Wet rice cultivation[6]
In wet rice cultivation, the land is thoroughly ploughed and flooded with water upto 5cm in depth. In case of clayey or loamy soil the depth of the water is upto 10 cm. Post puddling the land is levelled so as to ensure uniform water distribution. Seedlings are sown or transplanted after leveling.

Rainfed agriculture[7]
In rainfed agriculture cultivation predominantly depends on rains, allowing single or double crops as per the rainfall pattern of the region.

Irrigated agriculture[8]
In irrigated agriculture water is provided artificially to crops. Irrigation systems draw water from surface and groundwater sources and are also designed to harvest and channel rainwater. Irrigation systems generally consist of diversion channels, surface drainage tanks and wells. Diverting or storing and lifting water from rivers and streams with the help of dams and a network of canals as well as field channels is the most popular system for using water for irrigation. Groundwater is lifted from wells, borewells and tubewells with the help of non-mechanised and mechanised devises. In mountain regions hill streams and glaciers are the assured sources of water and these are tapped by a variety of diversion channels using gravity flow, taken directly to the fields or stored for future use.

Subsistence agriculture
Subsistence agriculture occurs when farmers grow food crops to meet the needs of themselves and their families. In subsistence agriculture, farm output is targeted to survival and is mostly for local requirements with little or no surplus.

High altitude Barley in the Yarlung-Tsangpo Basin

AGRICULTURAL SYSTEMS in the Yarlung-Tsangpo-Siang-Brahmaputra-Jamuna river system are dynamic and have been shaped over centuries by farming households living within specific ecological and social ecosystems in each basin and sub-basin of the river system. Most agricultural systems integrate crops and livestock, the level of integration differing according to the natural environment, climate, nutrition and economic needs of the households, and social and community influences. Farming households have adapted farming practices to changing circumstances, natural, ecological, social, political, and the prevailing policy environment. Climate variations, droughts and floods are important drivers for changes in cultivation practices and crop diversification in the river system.

Agropastoral households in the Yarlung Tsangpo basin with its high altitude, low temperatures, short growing season, and variable climate follow a unique plateau agriculture and livestock management system. Indigenous communities in the Siang basin with its hilly terrain and plant agrobiodiversity practice shifting cultivation, an agricultural system strongly linked to their culture. Terraced agriculture is practiced in the hilly regions of the Manas and Teesta sub basins. Wet rice cultivation is practiced in the lower reaches of the river system in the Brahmaputra and Jamuna basin. Tea has a special place in the culture of Yarlung Tsangpo and an intriguing history in the Brahmaputra Valley. Rice is a common crop throughout the river system except in the high altitudes where barley and wheat are grown.

Wet rice cultivation in the Brahmaputra and Jamuna Basin

Water availability either by means of rainfall or irrigation is an important determinant of the farming practice and cropping pattern adopted by farming households. The dry season rice cultivated in the Jamuna basin and Brahmaputra basin is largely dependent on irrigation. A recent study[1] estimates that the quantity of water used for irrigation from the river system in the Jamuna Basin in Bangladesh is highest during winter months when the dry season rice is in its early stages of cultivation, and before the spring rains arrive. In the Brahmaputra Basin in India the quantity of water used for irrigation is highest in March, in the early stages of the first growing season of the year.

This chapter provides an overview of agricultural systems, major crops and livestock, in four main basins and two sub-basins located within the Yarlung-Tsangpo-Siang-Brahmaputra-Jamuna river system and highlights the unique characteristics of the agricultural systems in each basin and sub-basin.









AGRICULTURAL SYSTEMS in the Yarlung-Tsangpo-Siang-Brahmaputra-Jamuna river system

– compiled by Vasudha Pangare

YARLUNG TSANGPO BASIN [9,10]

Agroecological/agroclimatic zone & elevation	Agricultural systems	Major crops and livestock
Temperate semi-arid and arid zone. Mean 4920 – 4949 m	Agropastoral	Cattle, yak, sheep, goat Barley
Sub-frigid, semi-arid zone. Mean 4870 m	Agropastoral	Cattle, yak, sheep Barley
Sub-frigid, semi-humid zone. Mean 4499 m	Agropastoral	Cattle, yak, sheep, goat, chicken Barley, spring wheat, pea, rapeseed, apples, peaches, potatoes, vegetables in greenhouses
Temperate humid or semi-humid zone. Mean 4145 m	Crop based livestock production Rainfed agriculture Irrigated agriculture	Yak and zo Cereals, rapeseed
Sub-tropical humid. Mean 1642 – 2552 m	Agroforestry pastoral mixed production systems Shifting cultivation	Yak, cattle, swine, goat Winter wheat, winter barley, maize, rice

SIANG BASIN [11]

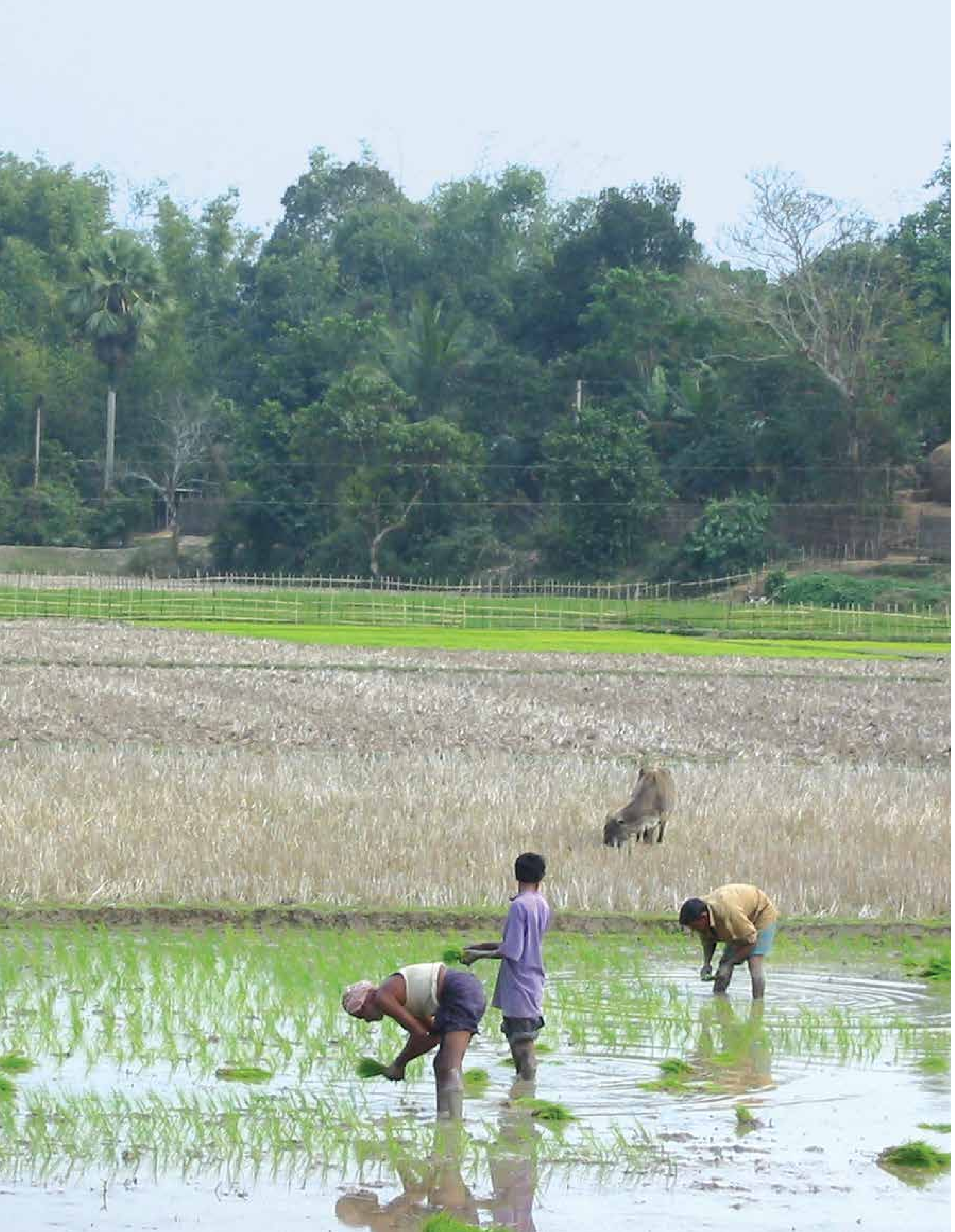
Agroecological/agroclimatic zone	Agricultural system	Major crops and livestock
Alpine zone 3500 + m	Transhumant pastoral	Yak, Dzo-Dzomo, sheep
Temperate sub-Alpine zone 1500 – 3500 m	Shifting cultivation	Barley, wheat, rice, millet, maize, potato, buckwheat, pulses, mustard, Aram Apple, plum, peaches, pears, walnut, vegetables Yak, Dzo-Dzomo, sheep, pig, goats
Sub-tropical hill zone 1000-1500 m	Shifting cultivation Terraced agriculture: rainfed and irrigated	Upland rice, maize, finger millet, beans, tapioca, yam banana, sweet potato, ginger, cotton, tobacco, chilli, sesame, vegetables Citrus, pineapple, pome and stone fruits Pig, cattle, Mithun, goats
Mild tropical plain zone <200 m	Wet rice cultivation	Rice, oilseed, sugarcane, jute, potato, sweet potato Buffalo, cattle, pig

BRAHMAPUTRA BASIN [12,13]

Agroecological/agroclimatic zone	Agricultural system	Major crops and livestock
Central Brahmaputra Valley zone	Wet rice cultivation Tea cultivation	Rice, maize, potato, vegetables and oilseeds Tea Jute Cattle, poultry, goat, pig, buffalo
Hill Temperate zone	Shifting cultivation	Rice, maize, sesame, cotton, tapioca, ginger, turmeric, arum, cucurbits, beans Poultry, cattle, goat, pig, sheep
Lower Brahmaputra Valley zone	Wet rice cultivation Tea cultivation	Rice, maize, potato, vegetables and oilseeds Tea Poultry, cattle, pig
North Bank Plain zone	Wet rice cultivation Tea cultivation	Rice, maize, potato, vegetables and oilseeds Tea Poultry, cattle, pig, Buffalo
Upper Brahmaputra Valley zone	Wet rice cultivation Tea cultivation	Rice, maize, potato, vegetables and oilseeds Tea Poultry, cattle, pig, Buffalo

MANAS BASIN [14]

Agroecological/agroclimatic zone	Agricultural system	Major crops and livestock
Alpine zone 3,600-7,500 m	Transhumant pastoral	Yak, sheep, goat
Cool temperate zone 2,600-3,600 m	Transhumant pastoral Livestock rearing Rainfed agriculture	Yak, sheep, goat Wheat, potato, buckwheat, mustard, barley
Warm temperate zone 1,800-2,600 m	Terraced agriculture; irrigated	Rice, wheat, potato, seasonal fodder, vegetables
Dry sub-tropical zone 1200-1800 m	Rainfed and irrigated agriculture	Rice, maize, mustard, barley, legumes and vegetables
Humid sub-tropical zone 600-1200 m	Terraced agriculture; irrigated	Wheat, mustard, Cardamom at higher elevations Mandarin orange at lower elevations
	Rainfed agriculture	Maize, millet, mustard, legumes, ginger, vegetables
Wet Subtropical zone 100-600 m	Subsistence agriculture; irrigated	Rice, wheat, maize
	Rainfed agriculture	Maize, millet, legumes, mustard, Niger, tubers, vegetables



TEESTA BASIN[15]

Agroecological/agroclimatic zone	Agricultural system	Major crops and livestock
Temperate zone 1524 – 2743 m	Subsistence agriculture	Wheat, barley, high altitude maize, potato, cabbage, beans, peas, apple, peach and pear Cattle, poultry, goat
Sub-tropical hill zone 610 – 1524 m	Terraced agriculture Agroforestry	Maize, rice, cardamom Cattle, goat, buffalo
Alpine zone 3962 +	Transhumant pastoral Agropastoral	Yak, dzo, sheep, goats, ponies
Sub- temperate zone 2743 – 3962 m	Shifting cultivation Terraced agriculture	Barley, wheat, potato, cabbage, apple, maize, peas, peach, medicinal plants, tubers Cattle, poultry, goat, ponies

JAMUNA BASIN[16]

Agroecological/agroclimatic zone	Agricultural system	Major crops and livestock
Old Himalayan Piedmont Plain	Wet rice cultivation Irrigated agriculture	Rice, potato, wheat, maize, sugarcane
Active Teesta Floodplain	Wet rice cultivation Irrigated agriculture	Rice, potato, mustard, maize, wheat, tobacco Poultry, cattle
Teesta Meander Floodplain	Wet rice cultivation Irrigated	Rice, wheat, maize, potato Poultry, cattle
Karatoya-Bangali Floodplain	Wet rice cultivation, irrigated	Rice, field pea, mustard, onion, lentil Poultry, cattle
Lower Atrai Basin	Wet rice cultivation, rainfed and irrigated	Rice, wheat, mungbean
Active Brahmaputra-Jamuna Floodplain	Wet rice cultivation	Rice, potato, mustard, wheat, maize, sugarcane Poultry, cattle
Young Brahmaputra and Jamuna Floodplain	Wet rice cultivation	Rice, potato, mustard Poultry, cattle
Old Brahmaputra Flood Plain and Jamuna Floodplain	Wet rice cultivation	Rice, mungbean, potato, maize Poultry, cattle

YARLUNG TSANGPO BASIN

The Yarlung Tsangpo Basin is located in southern Tibet, and includes major parts of Shigatse, Lhasa and Shannon prefectures and part of Nyingchi prefecture. This region is the main agricultural area of Tibet Autonomous Region. Most of the population is concentrated here, along the Yarlung-Tsangpo, Lhasa and Niachu rivers.

Agroclimatic zones and agricultural husbandry

Jin Tao

TIBET AUTONOMOUS Region is the main body of the Qinghai Tibet Plateau, with an average altitude of more than 4,000 meters. In terms of its typography, the continuous mountains and rivers divide Tibet into three different natural areas: the northern Tibet Plateau, the southern Tibet Valley and the eastern Tibet mountain canyon. With the change of temperature and precipitation, the huge height difference has formed a variety of agricultural climate zones and unique climate characteristics: strong solar radiation, rich sunshine, low temperature, less accumulated temperature, temperature decreases with the rise of altitude and latitude, large daily temperature difference, clear dry and wet periods with more rain at night; long dry and cold winter with more gale; cool and rainy summer with more hail.

Figure 1. The trend and distribution of the Qinghai Tibet Plateau mountains

North Tibet Plateau - grassland animal husbandry ecological area

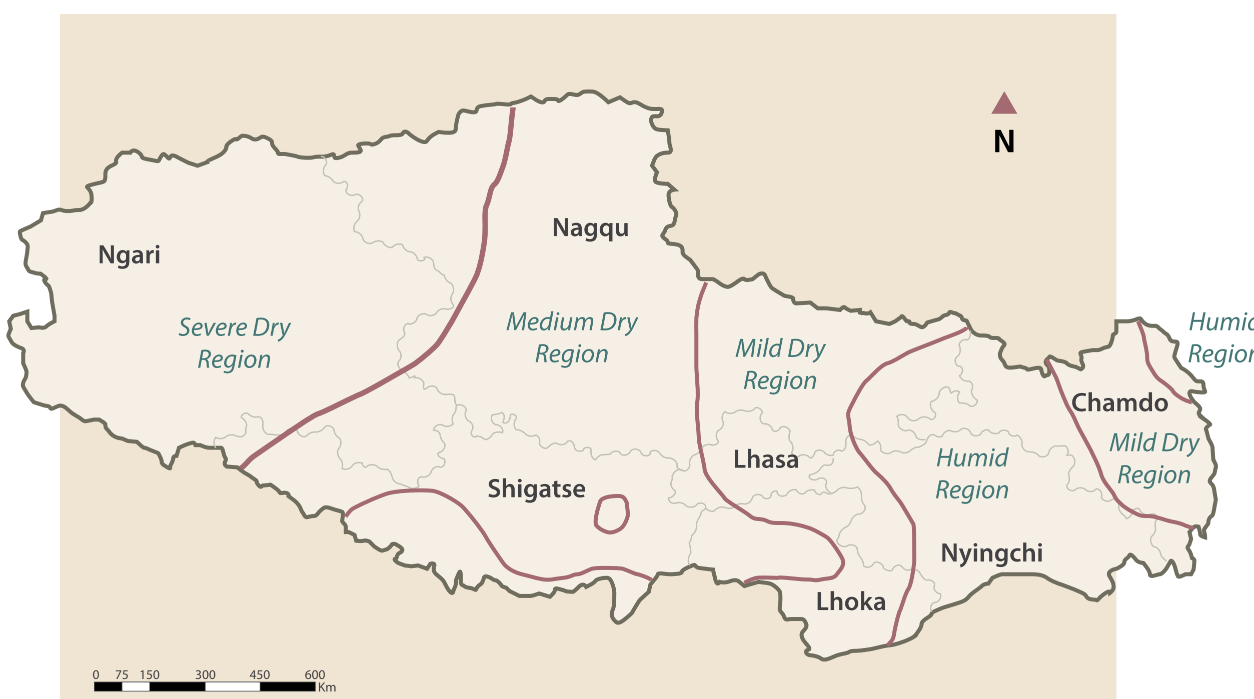
Located in the alpine zone between Kunlun Mountains, Tanggula mountains and Mountain Kailash - Nyainqêntanglha mountains, with an average altitude of more than 4,500 meters, this area accounts for about two-thirds of the land area of Tibet Autonomous Region. The average temperature in July, the warmest month, is less than 6 °C. There is freezing all year round. In the northern Tibet plateau north of Shiquanhe, Ando and Naqu, the average temperature at the surface of 80 centimeters in winter is between - 4 ~ 7 °C. Permafrost is widely developed, with almost no crop growth. There is a vast natural grassland, mainly composed of a small number of native grass types. It is the main grassland animal husbandry area of Tibet Autonomous Region, and the number of livestock accounts for about 30 percent of the total number of over 17 million livestock in the region. Yaks, sheep and goats are the main livestock types in this area. There are a small number of horses and pigs in the area below 4,000 meters above sea level.

The huge height difference has formed a variety of agricultural climate zones and unique climate characteristics

South Tibet Yarlung Tsangpo valley – agricultural and husbandry ecological area

This area is located between the Gangdise mountains and Himalayas, i.e. the Yarlung Tsangpo River and its tributaries. The average altitude is 3,500 meters. There are many flat valleys and lake basins with different width such as Lhasa River, Nyanchu River, Nyang River and other valleys, which are usually 5-8 kilometers wide and 70-100 kilometers long. The climate is relatively mild, the annual average temperature is 5-8 °C, the average annual precipitation is 300-450 millimeters, the frost free period is 120-150

Figure 2. Dry farming map of Tibet



Yak dung cakes stored for fuel in Tibet

days, the average temperature in the warmest month is about 15 °C, the accumulated temperature ≥ 10 °C is about 2,000 °C, and 85 percent of the annual precipitation is concentrated from June to September. The crops can be ripened once a year. The main crops are winter wheat, highland barley, rape, pea, potato, green feed, etc. The economic forest fruits in the temperate zone such as apples and walnuts can also be planted, as the area is suitable for the growth and planting of a variety of cool crops. The vast majority of highland barley is spring highland barley, and winter highland barley is only distributed in the valley agricultural area below 3,700 meters above sea level; winter wheat is the main wheat, accounting for more than 70 percent, the rest is spring wheat; beans are mainly peas, and some potatoes. This area has a concentrated population, a vast grassland, relatively flat terrain, concentrated arable land, and good soil conditions suitable for crop growth. The per unit yield of crops is the highest in Tibet, and it is the most important agricultural region with the combination of agriculture and animal husbandry in Tibet Autonomous Region.

Eastern Tibet - agriculture, forestry and animal husbandry ecological area

Located to the east of Naqu City, this region has a series of high mountains and deep valleys that gradually turn from east-west to north-south. The main part is Jinsha River, Lancang River and Nujiang River (referred to as Sanjiang River Basin) drainage area of Hengduan Mountains. It is high in the north and low in the south, with an altitude of 5,200 meters in the north, more than 3,000 meters in the south, and a height difference of more than 2,000 meters between the top and the bottom of the valley. The vertical difference in climate is obvious. The mountain top is often covered with snow all the year round, the hillside is densely covered with forests, and the Piedmont farmland is interlaced. It is a typical combination area of agriculture, forestry and animal husbandry. This area is the place with the best temperature conditions in Tibet. The annual average temperature is above 15 °C, frost free period is more than 270 days, the average temperature in the warmest month (July) can be more than 20 °C, the average temperature in the coldest month (January) is also above 8 °C, the annual accumulated temperature of ≥ 10 °C can be as high as 4700 ~ 5100 msl, the rainfall is abundant, and the annual average precipitation is more than 600 millimeters. It is the main natural forest area in Tibet, and the income from forest products is the main source of income for farmers in this region. The cultivated land area is small and scattered, most of which is distributed in the valley area or hillside terrace. Every year, the crops can be planted for two to three seasons, suitable for planting corn, rice and other warm food crops, as well as sugarcane, tea, citrus, oil tea, banana and other subtropical economic crops and forest fruits.

The rest of Tibet is basically a sub cold climate, with an annual average temperature of - 0.6 ~ 4 °C and an average temperature of about 10 °C in the warmest month (July). There are many natural disasters and frost almost all year round. Most areas are pastoral areas. Only in some places with good microclimate environment can spring barley and roots of *genkwa*[17] (Daphne) be planted.

The three basic factors of heat, water and soil in the region determine agricultural production and crop distribution

General overview of agriculture and animal husbandry in Tibet

High altitude terrain, low temperature, cold and changeable climate, short effective growth period of plants, slow growth and development of animals, has formed a unique plateau agriculture and animal husbandry, which also makes the output of agricultural and livestock products in Tibet low. The three basic factors of heat, water and soil in the region determine agricultural production and crop distribution, among which heat condition is the key. Altitude has a significant effect on temperature in Tibet, and the difference of temperature limits agricultural production and crop distribution. The total area of Tibet Autonomous Region is 1.2,284 million square kilometers. The cultivated land is distributed in strips or sheets along rivers. The cultivated land area is about 350,000 hectares, accounting for 0.3 percent of the total area. The valley cultivated land accounts for 70 percent of the total area of Tibet cultivated land. The grassland area is about 82.07 million hectares, accounting for 71 percent of the total area. The forest land area is 17.9,819 million hectares, accounting for 14.6 percent of the total area. The main areas of agricultural and animal husbandry production in Tibet Autonomous Region

Sheep account for 60% of the total livestock in Tibet

are the grassland animal husbandry ecological area located in the North Tibet Plateau and the agricultural and animal husbandry ecological area located in the South Tibet River Valley.

The main crops planted in Tibet include winter and spring barley (naked barley), winter and spring wheat, rape, pea, potato, and buckwheat. Rice, corn, soybean, millet, chicken claw grain and other crops are also planted in the area below 2,300 meters above sea level. Among the crops, highland barley has the largest planting area, about 180,000 hectares, wheat 41,000 hectares, rape 28,000 hectares, green fodder 48,000 hectares and vegetables 30,000 hectares. The average yield of spring highland barley is about 4,200 kilograms per hectare, wheat 4,700 kilograms per hectare, beans 3,800 kilograms per hectare, rapeseed 2,000 kilograms per hectare, vegetables 29,900 kilograms per hectare and forage 8,500 kilograms per hectare.

Tibet's livestock and poultry are mainly yak, sheep, goats, pigs, horses, donkeys, mules, and chicken. The main livestock are cattle and sheep, of which sheep account for 60 percent of the total livestock, cattle account for 36 percent, and other livestock account for a relatively small proportion. The average body weight of local adult yaks is 200 kilograms, the heaviest of which can reach 400 kilograms, and they will be released in 7-9 years of breeding; the weight of sheep may be between 40 to 50 kilograms, the heaviest being 60 to 70 kilograms; and the weight of adult goats may be between 25 to 30 kilograms; pigs are mainly local Tibetan pigs, with the weight of 30 kilograms, mainly distributed in forest and agricultural ecological areas.

Agriculture

Xiawei Liao

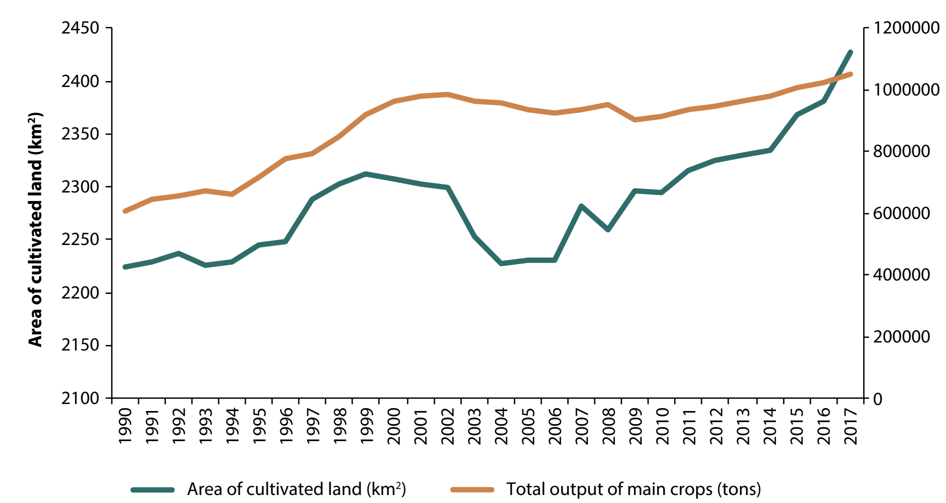
Agricultural GDP[18]

The gross output value of agricultural products in Tibet, including farming, forestry, animal husbandry and fishery, has more than tripled from RMB 5.1 billion (approximately US$ 0.73 billion) in 2000 to RMB 17.8 billion (US$2.54 billion) in 2017, and is approximately 13.5 percent of the provincial GDP. Animal husbandry contributed the largest share, 51.7 percent, to the provincial agricultural GDP, followed by farming products, 44.0 percent. Forestry products and fishery make up very small proportions, 1.7 percent and 0.2 percent respectively in 2017.

Crops

Out of Tibet's total land area of about 1.2 million square kilometers, most of which is made up of highland deserts and glacier areas, only less than 2,500 square kilometers land was cultivated for agricultural use in 2017, and the total crops output was 2,427.5 tons. Figure 3 shows the area of cultivated land and total crop output in Tibet from 1990 to 2017.

Figure 3. Area of cultivated land and total crop output in Tibet



The gross output value of agricultural products in Tibet, including farming, forestry, animal husbandry and fishery, has more than tripled in the last 15 years

About 55 percent of the cultivated land is used to grow highland barley (Figure 4). Among the 74 counties in Tibet, there are in total 65 counties growing highland barley, at altitudes ranging from 800 to 4,750 meters. Wheat occupied the second largest area of land, but with a decreasing trend from about 20 percent of the total cultivated land in 1990 to only 13 percent in 2017. A decreasing proportion of land is being used to grow beans as well, from 10.56 percent in 1990 to 1.56 percent in 2017. On the other hand, growing proportions of land are being used to grow vegetables and green feed, which together occupied 20.92 percent of the cultivated land in 2017.

Figure 4. Composition of crop productions in Tibet

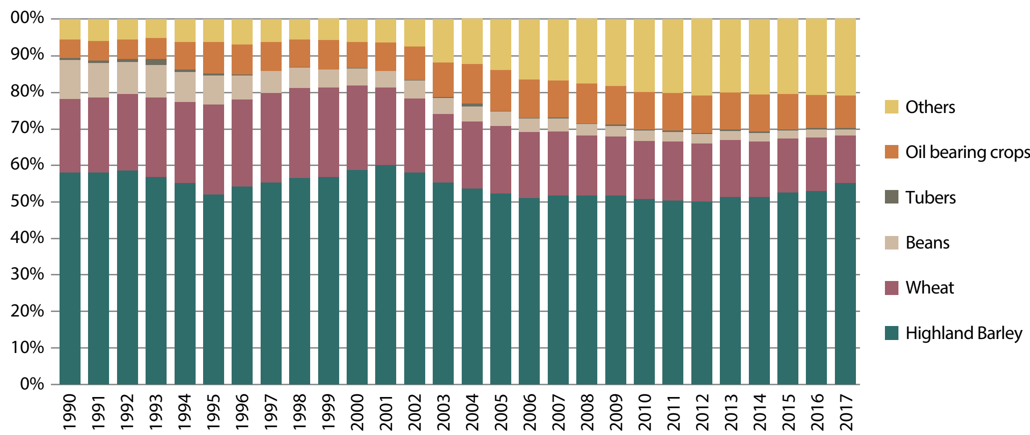
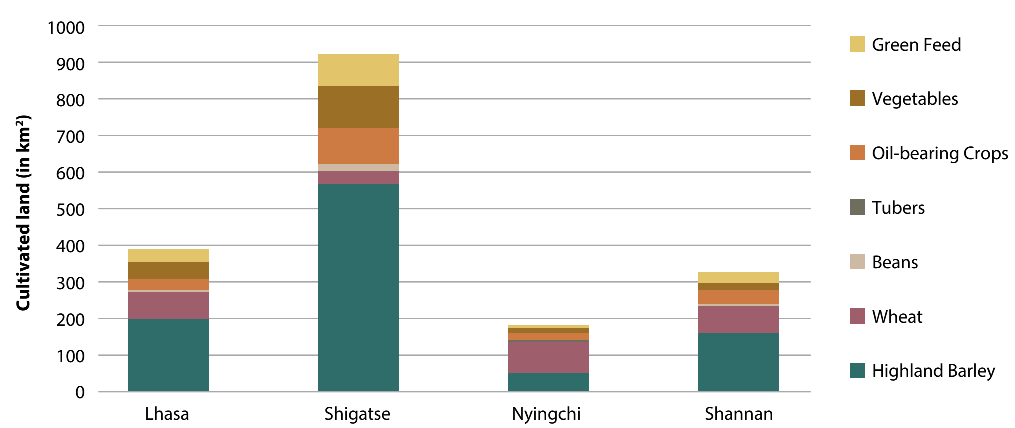


Figure 5 shows the land cultivated under various crops in the Tibetan prefectures in the Yarlung Tsangpo Basin in 2017.

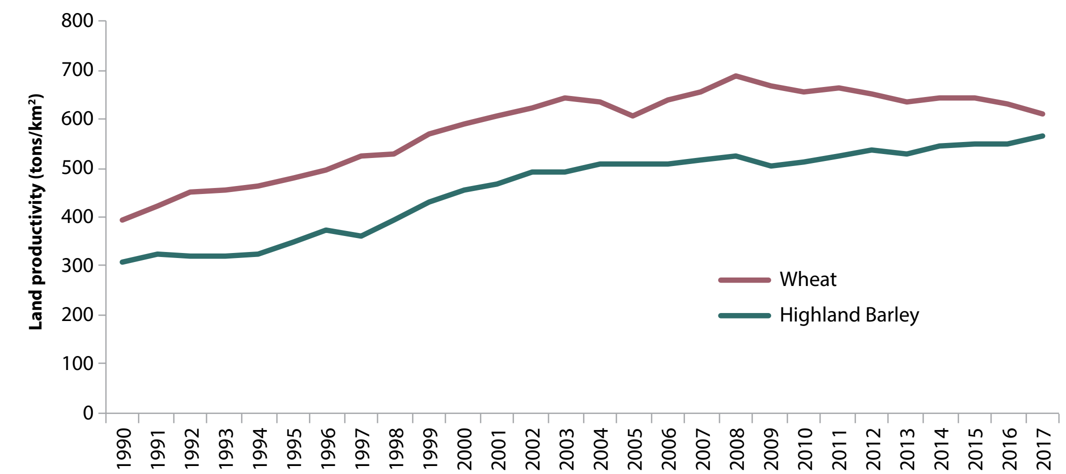
Figure 5. Cultivated land in main Tibetan prefectures in the Yarlung Tsangpo Basin in 2017



Highland barley has the largest production in Tibet, more than doubled from 0.37 million tons in 1990 to 0.79 million tons in 2017, which is followed by wheat productions. However, after peaking at 0.31 million tons in 2000, wheat production has kept decreasing to only 0.2 million tons in 2017, almost the same production level as in 1992.

Tibet has implemented various measures to increase the land productivity, such as scientific fertilization, mechanical seeding, pest and disease control. From Figure 6, it can be seen that land productivity for both highland barley and wheat has increased substantially over the last 30 years, from 307 (highland barley) and 393 (wheat) tons per square kilometers in 1990 to 566 (highland barley) and 609 (wheat) tons per square kilometers in 2017.

Figure 6. Land productivity for highland barley and wheat in Tibet



Tea, apple and pear plantations are occupying increasing land in Tibet, growing substantially from 1.49, 5.08 and 0.41 square kilometers respectively in 1990 to 7.90, 28.76 and 4.32 square kilometers in 2017. Accordingly, annual tea output has grown from 66 tons to 91 tons during the same period, while apple and pear productions have grown from 3,696 and 319 tons, respectively to 11,044 and 1,309 tons.

Initial evidence indicates that increase in cropping intensity on the Tibetan plateau could be attributed to climate warming

The effective irrigated area in Tibet has increased from 1,543.7 square kilometers in 2001 to 1,810.8 square kilometers in 2017, occupying an increasing share in the total cultivated land from 67.10 percent to 76.92 percent. Among which, the areas that are irrigated electromechanically have increased from 58.1 square kilometers to 69.8 square kilometers during the same period.

Initial evidence indicates that increase in cropping intensity[19] on the Tibetan plateau could be attributed to climate warming. The area suitable for single cropping increased from 19,110 square kilometers in 1970s to 19,980 square kilometers in 2000s, expanding from the downstream valleys of Lhasa River and Nyang Qu River to upstream valleys. The area suitable for double cropping gradually increased from 9 square kilometers in 1970s to 2,015 square kilometers in 2000s, expanding from the lower reaches of Yarlung Tsangpo in Lhoka Prefecture to the upper ones, as well as the Lhasa River tributaries. The upper limit elevation suitable for single cropping rose vertically from 5,001 meters above sea level to 5,032 meters above sea level from 1970s to 2000s, and that of double cropping rose from 3,608 meters above sea level to 3,813 meters above sea level.

Organic farming

From 2015 to 2017, total chemical fertilizer use per hectare has steadily decreased from 255 kilograms to 213 kilograms. Nitrogen fertilizer is occupying a decreasing share, from 52.15 percent to 32.64 percent while compound fertilizer is occupying a growing share, from 27.85 percent to 42.53 percent.

In recent years, accompanying the decreasing consumption of chemical fertilizers, organic farming has seen an expansion in Tibet. In 2019, a new project proposes to implement organic barley farming in more than 2.9 square kilometers in Linzhou County in Lhasa, which is expected to benefit 3,089 people in 510 households bring on average RMB 6,900 (approximately USD 975) income increase per household and RMB 1,168 (approximately USD 165) income increase per capita[20].

In Gangba County in Shigatse City, through organic farming and certification, the price per one sheep has increased from 800 RMB (approximately USD 113) to 1700 RMB (approximately USD 240.26) in 2016 and the total economic output of sheep farming in Gangba has reached RMB 1.53 billion in 2016, increasing by RMB 0.9 billion from 2013. It has led to income per capita increase of RMB 1,500 for sheep farmers [21].

Main agricultural pests

Almost 50 percent of the total cultivated land in Tibet is affected by crops diseases, pests and the problem of weeds. Every year, 10 to 30 percent of agricultural production is affected.

The main insect pests include locusts, aphids, underground pests, spiders, and caterpillars[22]. The main diseases are barley bacterial stripe disease, stripe disease, wheat rust, and smut. Locust is a unique species in the Qinghai Tibet Plateau, which has three characteristics of migration, outbreak and destruction. Affected by the continuous climate change, it seriously endangers the production of agriculture and animal husbandry, food security, income increase of farmers and herdsmen, and even the ecological environment. Aphids are mainly wheat aphids, rape aphids and other insect pests. They are very fast in reproduction speed, covering the whole Tibetan area. Red spider (*Tetranychidae*) is widely distributed and can cause harm to many plant species. They have very strong reproductive capacity, especially in high temperature and drought climate.

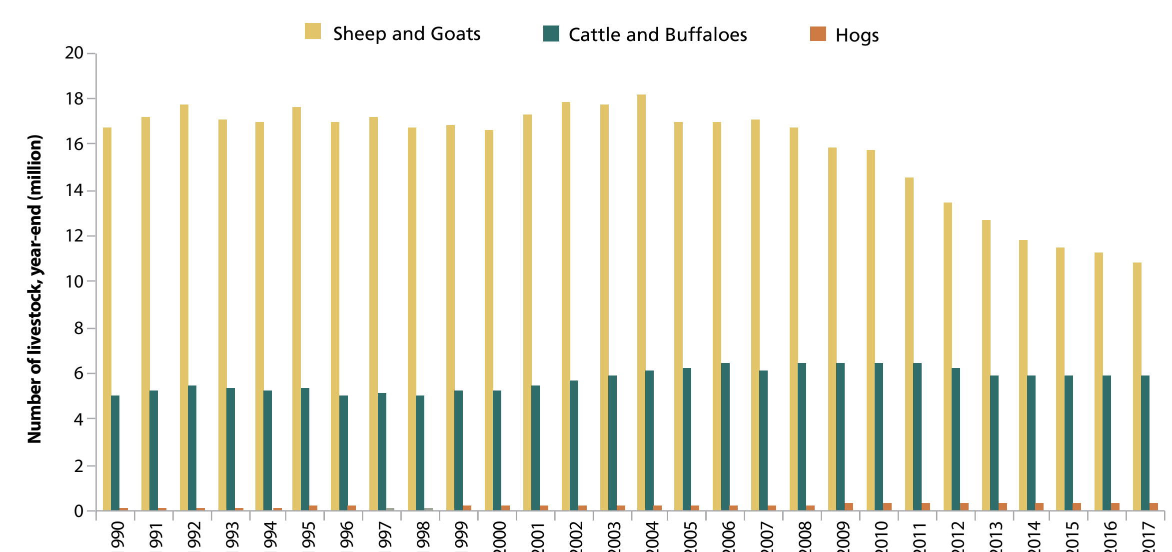
Traditionally, knapsack hand sprayer is used to spray pesticides for pest and disease control, which is labor intensive. After 2015, coordinated prevention and control has been promoted in Tibet, adopting large-scale pesticides application and spraying machines.

In recent years, accompanying the decreasing consumption of chemical fertilizers, organic farming has seen an expansion

Livestock

There are in total 0.88 million square kilometers of grassland in Tibet[23]. Animal husbandry makes up 44.9 percent of the provincial agricultural GDP and 19.4 percent of the provincial GDP. In total, there were 17.56 million livestock in Tibet in 2017. While the number of cattle and buffaloes has kept almost constant at around 6 million, the number of sheep and goats has decreased substantially from peaking at 25 million in 2004. The number of hogs has increased slightly from 0.16 million in 1990 to 0.42 in 2017. (Figure 7)

Figure 7. Number of livestock in Tibet



In terms of livestock products, more beef than mutton is produced in Tibet (Figure 8). In 2017, there were 225.4 thousand tons of beef and 63.5 thousand tons of mutton produced in Tibet, with only 11.4 thousand tons of pork. Diary production has increased by almost three times from 157.5 thousand tons in 1990 to 421.9 thousand tons in 2017. Milk production was 370.6 thousand tons in 2017. Figure 9 shows the livestock production in the main Tibetan prefectures in the Yarlung Tsangpo basin in 2017.

Figure 8. Livestock products in Tibet

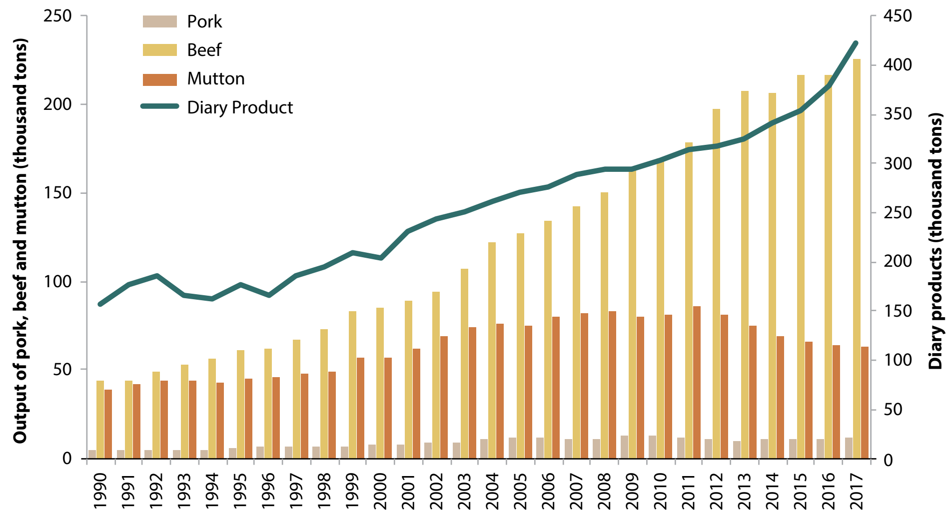
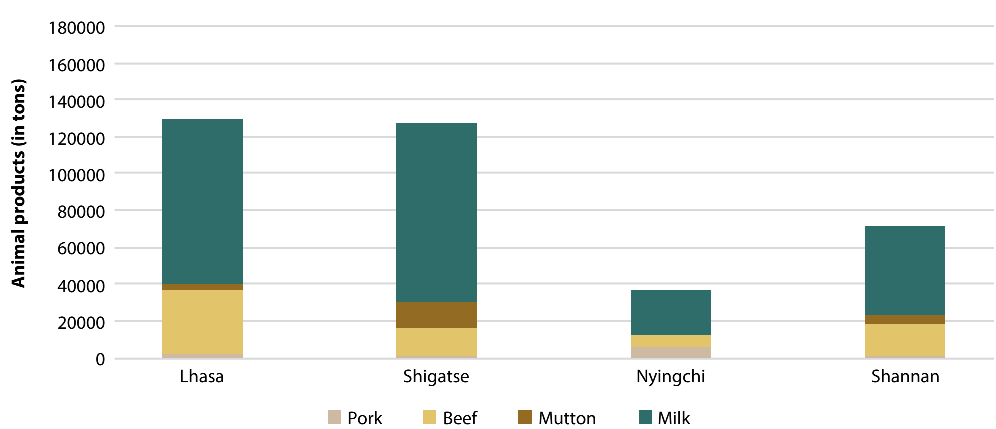


Figure 9. Animal products in main Tibetan prefectures in the Yarlung Tsangpo Basin in 2017



Greenhouses

TIBET IS rich in sunlight resources; the Direct Normal Irradiance is the highest among Chinese provinces. The utilization of greenhouses is a major component of agriculture modernization in Tibet. Greenhouses in Tibet are often built for vegetable growing in the warm season and for keeping livestock in the cold season. Plastic film for agricultural use has increased from 249 tons in 2001 to 1,843 tons in 2017[24].

Before greenhouse technology was adopted in Tibet, vegetable production had been low due to cold night temperatures. The promotion and utilization of greenhouses has basically solved the climate constraint for vegetable production. In 2011, the area under vegetable cultivation grew to 230 million square kilometers. The extent of greenhouses reached over 30 million square kilometers. In 2011, there were 214 green houses in Ngari prefecture, producing 2,074 tons of vegetables and supplying 50 percent to 80 percent of the vegetables in summer[25].

In 2017, over 60 million RMB (approximately 9 million USD) was invested in the Mozhu County in Lhasa to build a modern agricultural demonstration park. There are over 80 greenhouses in the park, with distribution centers and cold storage centers. Peppers, tomatoes, melons and eggplants are the main crops. The park has provided employment for over 80 people and paid an annual dividend of over 2,000 RMB (approximately 309 USD) to over 90 poor households[26].

Highland barley

Xiawei Liao

TIBETAN HIGHLAND barley, also known as naked barley and hulless barley,[27] is the main cereal crop cultivated on the Tibetan Plateau for at least 3,500 years[28]. It is one of the oldest crops of the world and even likely to be the first crop cultivated by humans[29]. It is called '*Qingke*' in Chinese and '*nas*' in Tibetan. Barley can be categorized by the number of its rows, ie. two-rowed, four-rowed and six-rowed hulless barley. While four-rowed hulless barley is the most common type in Qinghai province of China, six-rowed hulless (or naked) barley has been a major staple food of Tibetans for generations. It is used for food, feed, brewing and medicinal purposes. The sown area of highland barley occupies more than 50 percent of the cultivated land in Tibet[30].

Highland barley is a very important cereal crop in the Tibetan plateau due to its high level of cold tolerance, short growth period, high yield, early maturity and strong adaptability. Generally, spring barley is sown from March to May and harvested from July to September and the production period is about 100-130 days. The seedling can withstand the temperature of minus 10 degrees centigrade[31]. Winter barleys are normally sown in October.

Highland barley has higher nutritional components than rice, wheat and corn

Highland barley has higher nutritional components than rice, wheat and corn. Among food crops, highland barley is characterized by its high protein, high fiber, high vitamin, low fat and low sugar contents. Hou and Shen[32] examined the nutritional contents of 29 highland barley varieties in China and found that their protein content ranges from 8.74 percent to 13.15 percent and fat content ranges from 2.44 percent to 4.48 percent, differing substantially by varieties. Highland barley also contains oleic acid, linoleic acid, and linolenic acid and is rich in Vitamins B and C. The soluble fiber and total fiber are higher than other cereal crops. It has a higher content of microelements such

as calcium, phosphorus, iron, copper, zinc, manganese and selenium than corn. It also contains 18 kinds of amino acids, especially the ones that are essential for the human body[33].

Tibet has been improving the productivity of highland barley. From 1990 to 2017, the yield of highland barley per square kilometer in Tibet has increased substantially from lower than 400 tons to more than 600 tons per year[34]. Since 2013, Tibet has been promoting the cultivation of the barley variety '*Zangqing 2000*'; by 2016, over 50 percent of the total barley cultivation comprised of this variety.

TSAMPA made from Highland Barley is the staple food of Tibetan people. *Tsampa* is a dough made with roasted barley flour and yak butter. The roasted barley flour is mixed with boiled water or tea, ghee (yak butter) and kneaded into balls. The *tsampa* served with buttered tea is salty, while the *tsampa* made into porridge is often sweet. Tibetan people eat *tsampa* at every meal, and bring it along as a ready-made meal when traveling. The *tsampa* not only provides nutrition but also fortifies the people to withstand the cold climate.

SIANG BASIN

Vasudha Pangare

WHEN THE Yarlung-Tsangpo leaves China and enters India, the section of the river before it becomes known as the Brahmaputra, is called Siang. The Siang basin is divided into four agroclimatic zones ranging from an altitude of above 3,500 meters above sea level to below 900 meters above sea level. Shifting cultivation or *jhum* and settled agriculture on terraces and flat land are the two main agricultural systems in the mountain regions below 3,500 meters. Settled agriculture is both rainfed and irrigated.

Crops

Siang basin has a plant agrobiodiversity which supports the cultivation of about 70 crop species. Crop biodiversity is the main characteristic of the food supply system, contributing to its sustainability. About 134 plant species[35] are consumed by the people in this region. The agroclimatic zones and hilly terrain of the basin is conducive to the cultivation of spices, aromatic and medicinal plants, flowers, and mushroom. More than 80 percent of the crop production is organic is nature, cultivated without the use of chemical fertilizers and agrochemicals. Data available for the year 2017-2018[36] indicates that 81 percent of the cropped area is under organic practice.

There are two cropping seasons in the Siang Basin, monsoon or *kharif* (southwesterly monsoon season from July to October) and winter or *rabi* (post-monsoon season or winter season from October to March). Upland rice is the main crop and is grown in association with maize, finger millet, beans, tapioca, potato, ginger, mustard, and large cardamom. Sweet potato, cotton, tobacco, chilli, sesame and off-season vegetables are also grown. In general, the productivity is highest for rice in both the seasons. The production of pulses is 20 percent more in the *rabi* season[37].

Indigenous pig breed in Siang Basin

Mithun in Siang basin

Thirty-five percent of the net cropped area was under double cropping during the cropping seasons in 2016-2017[38]. Out of the total rainfed cropped area, 54 percent was under settled agriculture and 46 percent was under shifting cultivation. Approximately 17 percent of the gross cropped area was irrigated. Out of the total irrigated area, 46 percent was flat land and 54 percent was terraced. The nature of the terrain makes it difficult to install large irrigation systems in the region. Many traditional, community-based irrigation systems are still in use. These systems channel water from mountain streams and rivulets to the fields for irrigation purposes.

Livestock

Among the different species of livestock, yak, dzo-dzomo and sheep are reared mainly in high altitude alpine and temperate pastures and grazing lands. Mithun are reared almost all across the basin. The livestock census of 2012 shows a high increase in mithun population[39]. Cattle, goats and pigs are also reared in all parts of the basin except buffaloes which are found in warmer climates in the lower reaches of the basin. Pig rearing is a popular and traditional occupation since time immemorial. Most of the pigs reared are indigenous breeds. Pork constitutes 60 percent of the total food of animal origin consumed by the local population.

Apatani fish-rice cultivation[40]

Ganesh Pangare

THE APATANI tribe lives on the Ziro plateau located at an elevation of 1,572 meters above sea level in the Lower Subansiri part of the Siang Basin. This plateau lies between the Kamala, Khru and Panior ranges in the Eastern Himalayas. Traditional varieties of rice, *Amo* and *Mipa*, under wet rice cultivation, rainfed millet, maize, swine, poultry and fish are the important components of this unique agricultural system.

The knowledge of the traditional wet rice cultivation system has been passed down from generation to generation. Using natural gradients and contours to prepare and cultivate the fields and irrigate them, this farming system covers about 30 square kilometers of area in the villages of Hing, Siro and Ziro. The fields are separated by 0.6 meters high earthen dams supported by bamboo frames. These dams serve to hold water and soil in the fields. Millet is grown on these dams in order to strengthen them. Bamboo and pine are planted around the fields. Since the fields are located in valleys, the soil remains fertile due to the nutrient wash-out from the hill slopes. Fertility is maintained due to the manure which is available from the waste occurring from the pisiculture which is practiced in the rice fields and from the manure of domestic animals. Refuge from homesteads is also used; channels leading to the field carry refuse along with the rainwater from the habitation to the fields.

The rice fields are irrigated by an intricate system of channels and ducts which carry water from the Kele river and the streams that flow into it. The life of these springs and streams is closely dependent upon the health of the catchment from where they originate. The catchment has a good forest cover which is being preserved by the community. Water is distributed through a management system that ensures irrigation equitably to fields located in the upstream and downstream areas. After the upper fields receive their share of the water, the outlet channel is opened so that the next series of fields receive water. This method is followed until the last field is reached. However, in this process it takes some time for the water to reach the tail end. During this time the lower fields have to remain without water. To overcome this problem, a separate channel at the head is made from the mainstream through which water is diverted to fields located at the tail end. The place where the channel separates is called a *boring*. The community takes collective responsibility to maintain the systems and women contribute most of the labour required for maintaining the channels.

In the 1950s the Apatanis initiated an innovative method of fish-rice farming, in which fish is cultivated within the rice fields. Small pits are dug in the rice fields, filled with water and fingerlings are put in these pits. During the monsoon the fields are kept submerged with 5 to 10 cms of water. The fish move around in the entire submerged area. If water is scarce, the fish return to the pits and grow there.

The Apatani system of rice cultivation is not found anywhere else in the world. Research has proved that the system is highly efficient and helps to preserve the ecosystem in which it is practiced. The farming system is still largely organic in nature. The preservation of biodiversity in the area is closely linked with the practice of the Apatani rice farming system.

The Apatani system of rice cultivation is not found anywhere else in the world. The preservation of biodiversity in the area is closely linked with the practice of the Apatani rice farming system

SHIFTING CULTIVATION

Jhum: a misunderstood practice

Dhrupad Choudhury

SHIFTING CULTIVATION is the predominant agricultural practice in most of the catchment areas of the Siang and Brahmaputra basins. Locally known as *jhum*, the practice traditionally consisted of a short cultivation phase of one or two years – though exceptions exist and a cultivation phase of 4-5 years is also known - followed by a long fallow phase of over 25 years, sufficient to allow for rejuvenation of the soil and regeneration of the fallow into mature secondary forests. Common perceptions of the practice view it as subsistence, economically unviable and environmentally destructive. This perception views shifting cultivation solely as an agricultural practice and strives to replace it with settled agriculture. This view overlooks the fact that shifting cultivation is a sequential agricultural and forest management system that is practiced on the same plot of land but separated in time.

Shifting cultivation is a sequential agricultural and forest management system that is practiced on the same plot of land but separated in time

Shifting cultivators, or *jhumiyas* know that fallow forests are the backbone of *jhum* and hence diligently observe strict fallow management practices even as they clear a plot for cultivation. Plot preparation begins towards end November or early December when vegetation is carefully cleared from a pre-designated regenerating fallow. Branches of tall trees are lopped, while others are felled at breast height and the trunk left standing for coppicing after the first rains. Tree stubs and roots of selected plants are left undisturbed and together, these plant parts regenerate into new shoots at the onset of rains and as cultivation proceeds, setting the process of forest regeneration into motion. The slashed biomass is left to dry for about two months after which useful parts are retrieved from the plot for firewood, building houses, fencing and timber and the remaining debris set afire towards end February or early March. Fire is used to convert the biomass into ash and nutrients, hastening the process of decomposition, while also helping to control weeds and pests by killing off seeds and propagules of weeds, and eggs and larvae of pests through the intense heat generated during burning. Post burning, seeds of legumes, cucurbits, vegetables, spices and some cereals are dibbled into the soil while others, particularly upland paddy, millets and oilseeds are broadcast onto the slopes, thus following a 'zero tillage' practice. After cultivation for a year or two, the *jhumiya* moves to clear a fresh fallow, leaving the cultivated fields to rejuvenate and regenerate into fallow forests. *Jhumiyas* move to a new plot every second or third year in order to conserve soil nutrients and not 'bleed Mother Earth dry' - a move misinterpreted by scientists to indicate the depletion of soil nutrients.

A shifting cultivation landscape, in the cultivation phase is a rich repository of agro-biodiversity with an average of over 40 crops being grown, including diverse landraces of each crop. On a landscape level, shifting cultivation systems comprise of rich agro-biodiversity living gene banks, interspersed with a mosaic of different aged regenerating fallow forests. Viewed from this perspective, shifting cultivation, therefore, is not just an agricultural practice, but one that includes a sequential forest management practice at the landscape level. Ignorance of this view attempting to replace the practice has encouraged the promotion of wet terraces and permanent plantations at the cost of regenerating fallows, effectively shortening fallow cycles and permanently changing the landcover. The approach has resulted in erosion of forest cover and depletion of the rich agro-diversity in the process, severely restricting opportunities for harnessing the diverse agro-germplasm as building blocks for tomorrow's stress tolerant crops, or for safeguarding forests and the ecosystem services rendered by them, both essential for adapting to the growing challenges resulting from climate change.

JHUM CYCLE

December-January
selection of new plots based on presence/absence of some selective vegetation, type of soil, and the crop to be grown, followed by cutting and slashing

January-February
burning of slash and distribution of ash in the field; sowing of early rice and other location-based crops.

February-March
terracing of steep slopes and higher areas, preparing contours with half burnt old logs, weeds, stems, etc. and sowing of maize

March-April
sowing of some vegetables mainly in the boundaries, and tuber varieties along the peripheries that act as live fence for protection against animals

April-May
weeding and sowing of paddy by women with minimum soil disturbance

October-November
harvesting, grain kept aside for seed

Jhum: A cultural tradition

Vasudha Pangare

SHIFTING CULTIVATION or *jhum* is an age-old practice constituting a vital part of the socio-economic framework of tribal life. *Jhum* cultivation is not just a source of livelihood but is traditionally allied to the culture, customs and ethnicity of the people. Each stage and activity in the *jhum* cycle is associated with festivals and rituals, as indicated in location-specific traditional calendars of events.

A shifting cultivation landscape, in the cultivation phase is a rich repository of agro-biodiversity and is important for ensuring food security

Shifting cultivation is important for ensuring food security, as in addition to staple foods like rice and tubers, maize and millet, a broad range of vegetables and herbs as well as a large number of medicinal plants are grown in fields and fallows. Many varieties of rice are grown in the *jhum* fields. Various crops are grown on the contour bunds constructed with bamboo for soil conservation. Some farmers cultivate cash crops like turmeric, ginger and large cardamom for commercial purpose. Rice is also used for making local beer.

Indigenous women perform 70 percent of the work related to shifting cultivation[41]. They are responsible for the selection of seeds, for weeding the fields, gathering, processing, and selling the surplus products. Men do the identification of land suitable for shifting cultivation and the land preparation, women help in clearing the land. Sowing is done by women using the dibbling technique in which a small hole is made with the help of a sharp stick and two-three seeds are dropped into the hole. This technique involves minimum soil disturbance and requires expertise and practice. The dibbling and sowing of seeds are done exclusively by women, usually for crops such as maize, pulses, cotton, sesame and vegetables. Men broadcast seeds of crops like millets and small millets.

Both men and women make the firebreaks, harvest the crops, and conduct the rituals during the shifting cultivation cycle. Indigenous women possess a rich knowledge of seeds, crop varieties and medicinal plants, and transfer this knowledge to the younger generation. Indigenous women preserve seeds and play a key role in preserving agrobiodiversity.

BRAHMAPUTRA BASIN

Vasudha Pangare

FROM THE Siang Basin, the river enters the state of Assam. The section of the river that flows through Assam is known as the Brahmaputra. The Brahmaputra basin is situated between the hill ranges of the eastern and north-eastern Himalayan range in Eastern India. There are five agroclimatic zones in the Brahmaputra basin. Shifting cultivation is practiced in the hill temperate zone. Wet rice cultivation and tea cultivation are the main systems in the valley zones; rice is the main staple crop and tea is the main cash crop. Tea is grown in four agroclimatic valley zones. Assam is known for its tea gardens, and the world-renowned Assam tea gets its distinctive flavour from the soil and climate of the Brahmaputra valley.

Livestock contributes to food and crop production for smallholder farming households and are important as savings, as a source of daily cash income, and as insurance against adversity, particularly in the face of climate uncertainties

Crops

Five crop combination systems of rice, maize, potato, vegetables and oilseed are found in the fertile alluvial plains of the Brahmaputra Basin. This region is also the second largest producer of Jute in India. Jute is cultivated in an area of 75,140 hectares with an average yield of 1,923 kilograms per hectare.

Rice is a three-season crop; autumn, winter and summer[42]. Autumn rice is called *Ahu* and is usually sown in February–March and harvested in July–August. Winter rice or *Sali* is sown in July–August and harvested in November–December. Summer rice or *Boro* is sown in November–December and harvested in March–April. *Boro* is considered a low-risk rice with 30 to 40 percent higher yield[43]. Data for 2016-2017[44] shows that the average yield of *Ahu* (autumn) rice cultivation was 1,380 kilograms per hectare, the average yield of *Sali* (winter) was 2,023 kilograms per hectare, and the average yield of *Boro* (summer) rice was 2,773 kilograms per hectare.

Agriculture in the valley is challenged by floods and high rainfall, particularly in the *kharif* (monsoon) season. The State Agriculture Department[45] promotes *rabi* (winter) crops by developing irrigation facilities through the installation of Pump Sets (Shallow Tube Well & Low Lift Pump). Assured irrigation has been effective in raising cropping intensity to 146 percent[46].

Livestock

Almost 90 per cent of the rural households keep indigenous livestock of one species or the other; cattle, buffalo, sheep, goat, pig, poultry[47]. Livestock contributes to food and crop production for smallholder farming households and are important as savings, as a source of daily cash income, and as insurance against adversity, particularly in the face of climate uncertainties. Animal traction is still used. Cattle and buffalo are important for agricultural operations whereas milk production is secondary.

There are pockets of nomadic systems of cattle rearing, mostly in the fringes of the forests. In recent years, farmers have begun to keep improved livestock and commercial poultry. Livestock is largely fed on crop residues, and food waste. High-producing animals are given concentrated grain-based feed as supplements.

Coping with floods

Raju Mandal

ASSAM IS home to a large network of rivers. The rivers Brahmaputra and Barak, and their tributaries play an important role in the lives and livelihoods of people in the plains of the state. Because of its unique geological location in the foothills of the Himalayas the abundance of monsoon precipitations and fertile alluvial soil deposition by the rivers during rainy season have enabled majority of the population to depend on cultivation as the principal source of livelihood for generations. However, being located in a heavy rainfall zone, excessive precipitations in the state and upper catchment areas during monsoon cause widespread water logging and flood—sometimes four to five times in a year—in the plain areas of the state. The plains of Assam, covering 81 percent of total geographical area and accommodating 97 percent of total population of the state, are highly prone to floods[48]. The flood-proneness of Assam is around four times the national figure as 39.58 percent of total area of the state is flood-prone compared to the corresponding national figure of 10.2 percent[49].

Although flood is a known and regular annual phenomenon in Assam, its varying timing, intensity and frequency pose a great risk and uncertainty particularly for the crop growing sector. Floods in the early phase of the monsoon mainly damage the *Ahu* seasonal type of paddy. But floods occurring late in the season are most devastating as they damage the standing *Sali* paddy, which happens to be the main *kharif* (monsoon) crop of the state. Apart from causing instability in production, occurrence of frequent floods is one of the factors responsible for low rate of adoption of modern techniques of agricultural production.

Although flood is a known and regular annual phenomenon in Assam, its varying timing, intensity and frequency pose a great risk and uncertainty particularly for the crop growing sector

Notwithstanding the fact that the agriculture sector of Assam is highly exposed to flood risk every year, more than half of its workforce still depends on it for their livelihoods. Naturally the question arises as to how the farmers in the state are surviving in the face of flood induced production risks while they do not have any institutional safeguards like crop insurance. In this regard Goyari[50] and Mandal[51] using district level aggregated data have found that the attempt to minimize production risk arising out of recurring floods has led many farmers to adjust the cropping pattern and/or season as a result of which there has been a decline in the acreage shares of *kharif* (monsoons) food grains that are largely affected by flood, and a corresponding increase in the acreage shares of *rabi* (winter) food grains and vegetables. Such adaptations by the farmers have been possible particularly after the introduction of privately-owned shallow tube well based irrigation system in the state in the mid-1990s[52].

Analysis of farm level data and interactions with farm households by Mandal[53] reveals that the farmers who are exposed to greater risk arising from floods tend to adopt a cropping pattern that is more diversified across crops and seasons to hedge against flood induced risks and limitations in agriculture. Farmers with better irrigation facilities and access to institutional credit are found to be more successful in this strategy. This apart, the farms with a diversified cropping pattern have been able to extract more returns by compensating for losses in output of one or two crops by others that do not suffer such losses. These coping mechanisms by the farmers in the flood plains of Assam have important policy relevance for attaining and maintaining a higher growth rate of the agriculture sector and making farming a remunerative profession in the state.

MANAS BASIN

Kinlay Tshering and Vasudha Pangare

THE MANAS river, flowing through Bhutan is an international tributary of the Brahmaputra river.[54].

Bhutan is broadly divided into six major agroecological zones[55] corresponding with altitude range and climatic conditions, for the purpose of agricultural planning. At higher altitudes, livestock rearing is the most common source of livelihood, with some dryland farming. In the lower altitudes, agriculture is widely practiced in terraced irrigated wetlands and drylands. The main crop cultivated in the terraced irrigated wetland agricultural areas is rice 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 sloped dryland agricultural areas, maize, millet, mustard, several types of legumes, ginger and vegetables are the predominant crops.

Agricultural production

Agriculture[56] is one of the Five Jewels of the Economic Development Policy[57] of Bhutan. In 2017, the crop sector contributed about 10.64 percent of the total Renewable Natural Resources sector contribution to the country's Gross Domestic Product. Agriculture provides employment to 57.2 percent of the total population[58]. Although only 2.75 percent of the total land is under cultivation[59], agriculture production in Bhutan has made significant contribution to enhance food and nutrition security and reduce

Terraced rice fields in Bhutan

The main crop cultivated in the terraced irrigated wetland agricultural areas is rice followed by wheat and mustard rural poverty. Rice is the major crop associated with food security and has cultural significance for the people of Bhutan. It symbolizes a way of life and epitomizes environmental and landscape beauty.

With an average farm size of 0.89 hectares[60], often spread over different agro-ecological zones and altitudes, most farmers practice subsistence to semi-subsistence integrated farming systems. In many parts of the country, farmers continue to depend on the monsoon rains, which have become ever more erratic and unreliable. Though the country is blessed with many river systems, their use in agriculture had been limited due to unavailability of appropriate technology to tap irrigation potential. In 2017, assured irrigation covered about 27,500 hectares of cultivated land. In an effort to reduce irrigation water scarcity, 212 water harvesting reservoirs were constructed on cost sharing basis at various locations.

Rice is the major crop associated with food security and has cultural significance for the people of Bhutan. It symbolizes a way of life and epitomizes environmental and landscape beauty

Approximately 90 percent of rural farmers raise some form of livestock[61] for dairy products, draught power, meat, and dung. For most small holder farmers, livestock provide a ready source of income to help purchase the necessary inputs for crop production such as seeds and fertilizers. Most agro pastoralists graze their livestock in nearby forests and keep them in sheds during the night. Dung is used for crop production, greatly reducing or eliminating the use of chemical fertilizers. Cattle is most preferred because of its multiple uses. Poultry is raised for eggs and pigs for meat. Horses are used for traction and transport.

Over the last decade, farming in Bhutan has seen a dynamic shift from subsistent to commercialized farming. Farm mechanization has been promoted with power tillers and mini tillers, and rural accessibility has been improved. The major interventions that have triggered this transition process are investments in irrigation and farm roads; electric fencing to protect crops from wildlife damages (3,492 kilometers of electric fencing was installed across the country); development and promotion of high yielding crop varieties and protected cultivation; focused commodity approach, agricultural land development including sustainable land management practices and provision of essential support services including market infrastructures[62]. A total of 841 different post-production structures were established to reduce post-harvest losses and add value to agricultural produce.

Organic agriculture[63]

The Ministry of Agriculture and Forests launched the National Framework for Organic Farming in 2006. The inherently organic nature of Bhutanese farming systems guided the evolution of the country's development of organic agriculture. The approach and strategies promoted conservative, sustainable, self-sustaining, resilient production systems that prevented exploitation of ecosystems and sustainable use of natural resources. Under the National Organic Programme, about 10,387 hectares of land is currently under organic management, out of which 7,837.5 hectares comprises forest land certified for collection of various Non-Wood Forest Products.

About 2,650 households have been supported by the National Organic Programme to practice organic agriculture on 2,250 hectares of agricultural land. Training, inputs, infrastructure, equipment, product development and marketing support have been provided to the households. Twenty-four farmer groups/cooperatives have been formed. Three retailers, and one exporter support the production and marketing of organic produce. Three organic manure production plants have been established to supply bio-inputs for organic production.

The Local Organic Assurance System (LOAS) certification was established in 2017 for locally produced organic products. In collaboration with National Certification Body (BAFRA) and International Certification Body (IMO) for organic certification, 10 products have been certified including potato, garlic and carrot from Gasa, turmeric from Zhemgang, seabuckthorn, chamomile, mint from Bumthang, Green Tea from Trongsa, and rhododendron and lemongrass essential oils from Mongar.

A flagship program on organic agriculture was approved for implementation in the Twelfth Five Year Plan (2018-2023), to commercialize organic production for export and domestic market, and to make organic inputs available in the country on a larger scale.

TEESTA BASIN

Vasudha Pangare

THE TEESTA River originates in the Himalayas and flows through the Indian States of Sikkim and West Bengal before joining the Jamuna in Bangladesh. Flowing through the length of Sikkim, the Teesta River is considered to be the lifeline of the state. The basin has four agroclimatic zones. Shifting cultivation, terraced agriculture and subsistence agriculture are the main agricultural systems.

The hilly terrain and difficulty in access to markets has made villages self sufficient; most households are engaged in subsistence agriculture, and produce food grains for home consumption, with shortfalls being met by supplies under the public distribution system[64]. Milk is traded across the rural areas, in outside markets as well as in the milk cooperative society areas. Milk constitutes a major source of household income. Meat markets are local, confined to village clusters both in the case of beef and chevon. Eggs are traded among village clusters but the poultry meat is kept for home consumption[65].

Shifting cultivation, terraced agriculture and subsistence agriculture are the main agricultural systems. Most of the agriculture is organic and has traditionally been in practice since ages

Crops

Sikkim is rich in biodiversity with abundant plant species because of which the soil is rich in organic matter content and makes the nutrient conversion easier. Sustainable farming practices that conserve and maintain the fragile ecosystem are important for soil and ecosystem protection. A variety of crops can be produced because of the varied agroclimatic conditions in the basin. Most of the agriculture is organic and has traditionally been in practice since ages[66].

Agricultural holdings are spread between an elevation of 300 to 3,000 meters. Farming is done in about 10.20 percent[67] of the total geographical area of the state. Most of the cultivable lands are terraced. Marginal holdings and small holdings together comprise about 50 percent of all operational holdings and occupy 41 percent of the total area. Agriculture is largely rainfed with traditional system of cultivation and low inputs. Due to topographical features, medium/major irrigation projects are not feasible and therefore only minor irrigation channels are installed. About 11 percent[68] of the cultivated area is irrigated.

Traditional communities in the upper reaches of the basin, in the cool temperate and lower alpine zones between 2,500 to 4,000 meters, grow wheat, barley, and seasonal vegetables such as beans, potato, cabbage, cauliflower, and radish in the summer when the snow melts. Large cardamom-based and farm-based traditional agroforestry can be found in the subtropical to warm temperate zones at an elevation between 600 and 2,500 meters. Wet rice cultivation is practiced in terraces and along river valleys in the tropical zone at an elevation greater than 500 meters.

Other crops include maize, buckwheat, *urad* (black lentil) rice bean, soybean and mustard. Orange and pears are the main horticultural crops; ginger, cardamom, turmeric and cherry pepper are the main spice crops; peas, bean, tomato, potato are the main vegetable crops. Off-season vegetables are being cultivated extensively. In recent years, a large number of farmers have adopted floriculture as a commercial venture and the cultivation of flowers like cymbidium, rose, gerbera, anthurium is generating a good income.

Livestock

Livestock production had always been an integral part of the rural livelihoods in Sikkim and is predominantly the endeavour of small producers[69]. Marginal and small farmers own nearly 85 percent of all species of livestock and poultry, even though they own or operate less than 55 percent of the farmland in Sikkim. Even the tiny organised poultry industry in Sikkim is made up of small broiler farms. Over 80 percent of all rural households own livestock (often a mix of several species) as part of the traditional mixed crop-livestock farming system, earning substantial incomes and enriching family diets with nutrient rich animal products. Income from livestock is thus a substantial contribution to the subsistence farming systems in Sikkim.

❄

JAMUNA BASIN

Jamuna basin is one of the three major river systems of Bangladesh. The basin is often characterized as a granary or the breadbasket of the country

The Brahmaputra River flows through the Indian state of Assam and enters Bangladesh after the Assamese town of Dhubri. In Bangladesh the river is known as the Jamuna and is the last stretch of the river system before it meets the Ganges river.

Agriculture

Md. Ayub Hossain

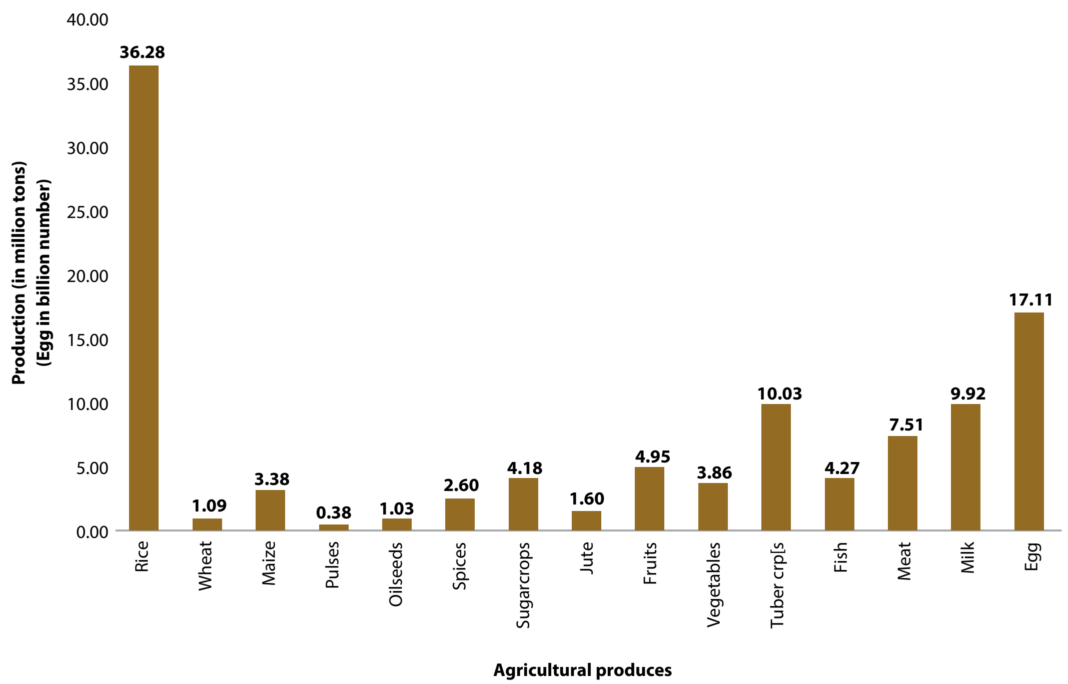
Agriculture systems in the basin

Jamuna basin is one of the three major river systems of Bangladesh. Brahmaputra-Jamuna and old Brahmaputra with their main tributary Teesta and a good number of small tributaries and distributaries constitute the largest floodplain of Bangladesh. The Brahmaputra-Jamuna drains the northern and eastern slopes of the Himalayas and has a catchment area of 5,83,000 square kilometers[70]. The administrative districts of Panchagarh, Thakurgaon, Dinajpur, Kurigram, Rangpur, Nilphamari, Lalmonirhat, Gaibandha, Joypurhat, Naogaon, Rajshahi, Bogura, Shirajganj, Pabna, Jamalpur, Mymensingh, Narayanganj, Munshiganj, Manikganj and Dhaka are included in the Jamuna basin[71]. The land of Jamuna basin is alluvial soil and it is fertile. Jamuna basin consists of eight agro ecological zones. The total area of the Jamuna basin is 3,962,077 hectares which is 27.67 percent of the total land area of Bangladesh[72].

Jamuna basin is often characterized as a granary or the breadbasket of Bangladesh. Agriculture or farming remains the mainstay of the people of this region. The crop profile includes multiple crops such as rice, cereals and cash crops such as sugarcane, oilseeds, pulses, and tobacco. Besides these, many fruits, vegetables and spices are also grown.

Agroforestry is a popular and widely practiced intervention in Jamuna basin. Agroforestry is commonly practiced in establishment of fruit orchards especially in early stages of plantation (1-3 years). Some shade crops like turmeric, ginger, and grasses, are cultivated in this area. Social forestry[73] is generally practiced by 39.4 percent of farmers for fuelwood, fruits, and timber. About 24.6 percent of households also practice roadside plantation, about 11.8 percent are involved in embankment cropping[74–75].

Figure 10. Agricultural production in Bangladesh in 2018-19



The soil of Jamuna basin is comparatively more fertile than other regions of the country. Most area of the basin is suitable for agricultural crop production

Crop production in the basin

The soil of Jamuna basin is comparatively more fertile than other regions of the country. Most area of Jamuna basin is suitable for agricultural crop production. There are three main seasonal types of rice grown in Jamuna basin; *aus, aman* and *boro* rice. *Aus* is a pre-monsoon rainfed crop, *aman* is a rainy season rice, whereas *boro* is irrigated rice grown during the dry winter season (January through May). Transplanted *aman* and *boro* rice are grown all over the Jamuna Basin. *Aus* rice is cultivated in some locations. Due to its higher yield potential (3.4 tons ha^{-1}) compared to *aus* (1.6 tons tons ha^{-1}) and *aman* (2.0 tons ha^{-1}), *boro* rice production has expanded in the last three decades[76]. *Boro* rice is widely cultivated, contributing about 55 percent of the overall rice production[77].

The main field crops in Jamuna basin are cereals (rice, wheat, maize, millets, etc.), pulses (lentil, grasspea, chickpea, mungbean and blackgram, etc.) oilseeds (mustard, groundnut, sesame, sunflower, etc.), vegetables (Potato, radish, tomato, brinjal, sweet gourd, pumpkin, bittergourd, pointed gourd, snake gourd, leafy vegetables, etc.) and spices (onion, chilli, garlic, ginger, turmeric, etc.). Different types of local and exotic fruits are grown in different seasons.

About 200 cropping patterns are followed in this region. The cropping intensity (211 percent) is higher than the national average (195 percent) of the country[78]. As a whole the crop diversity index of Jamuna basin is 0.90 which indicates a high crop diversity[79]. The region includes 7.58 percent single cropped area, 48.09 percent double cropped

area and 41.15 percent triple cropped area. The area and production of maize in Jamuna basin is increasing day by day. Farmers are cultivating mainly hybrid maize[80]. About 60 percent of total maize production in the country is in Jamuna basin[81].

Irrigation systems

The farmers of Jamuna basin practice multiple cropping system, hence the fields get irrigated more than once a year. The sum of these multiple gross irrigated areas is about 4.24 million hectares[82]. About 80 percent of Jamuna basin area is irrigated. Government organizations such as Bangladesh Agricultural Development Corporation, Barind Multipurpose Development Authority and Bangladesh Water Development Board

The positive benefit of increasing use of groundwater irrigation is that almost the whole region has achieved food self-sufficiency and has contributed significantly to rural wealth creation

are involved in executing some big irrigation projects. The country enjoys tropical monsoon climate with two prominent seasons; dry season (November-May) and wet season (June-October). Up to 85 percent of the annual rainfall occurs between June and September. Mean annual rainfall ranges from about 1,200 millimeters in the west to almost 6,000 millimeters in the northeast[83]. In Jamuna basin about 88 percent land is irrigated by groundwater and rest is irrigated by surface water. The positive benefit of increasing use of groundwater irrigation is that almost the whole region has achieved food self-sufficiency and has contributed significantly to rural wealth creation[84].

Irrigation is applied first in *Boro* rice and vegetable cultivation and then for wheat, maize, oilseeds and spices. *Aman* rice is mainly cultivated under rainfed condition, but sometimes supplementary irrigation is required if monsoon rain is not sufficient. Shallow tubewells and deep tubewells are the major groundwater lifting devices in Jamuna Basin area. There are also low lift pumps for surface water irrigation, but their numbers are insignificant and concentrated near the river and irrigation canal. About

Almost all rural households rear livestock

58 percent of the lifted water is used for *boro* rice cultivation and the rest is used for irrigating other crops. About 68 percent of the groundwater is lifted from shallow tubewells and rest from deep tubewells[85]. These pumps are operated by diesel engine, electric power and a few by solar energy. Solar irrigation pump is a new and emerging irrigation technology and is becoming popular in Jamuna basin. There are about 1,600 solar irrigation pumps operating in Bangladesh, among them about 60 percent are in Jamuna basin[86]. Most of the irrigation pumps are used on custom hire basis.

Fisheries and aquaculture

The fisheries sector, in Bangladesh, plays a crucial role among the poor as a main or additional source of employment, livelihood and income. The sector is the second largest part-time and fulltime employer in rural areas. Bangladesh produced 4.27 million tons of fish during 2017-18 from inland and marine waterbodies and aquaculture contributed more than 50 percent of the total production[87]. Fisheries accounts for 3.69 percent of Bangladesh GDP, 22.60 percent of agriculture sector and 2.5 percent of total export earnings. It also contributes 60 percent of the animal protein intake in Bangladesh. Bangladeshi people largely depend on fish to meet their protein needs[88]. Until the 70s, there was an abundance of fish in the natural waters-the floodplain, rivers, rivulets, *beels*, lakes, ditches and canals of the country to satisfy the demand of fish. Presently, capture fish production has declined to about 50 percent, with a negative trend of 1.24 percent per year[89].

In the past the major source of fish production in Bangladesh was the inland open water capture fisheries. Now aquaculture has become an emerging sector of fisheries in Bangladesh. Inland pond culture represents the mainstay of aquaculture in Bangladesh, accounting more than 80 percent total recorded aquaculture production and presently

dominated by carps (indigenous and exotic), pangas and tilapia. The aquaculture production both in fresh water and brackish water has significantly increased during the last two and a half decades with development of technology.

Inland fishery in Jamuna basin is composed of rivers, *beel* and ponds. The *beel* is a Bengali term used for a relatively large surface, static waterbody that accumulates surface run-off water through an internal drainage channel[90]. The most famous *beel* in the country known as the Chalan *beel* is located in Jamuna basin. In the Jamuna basin, 86 percent of total production of inland fish[91] is from aquaculture. Major inland fishes in Jamuna basin are major carp (*Rui, Catla, Mrigal*), minor carp (*Kalibaus, Bata, Ghania*, etc.) exotic Carp (Silver Carp, Grass Carp, Common Carp, Mirror Carp, Big Head Carp, Black Carp, etc.), cat fish (*Boal, Air, Silon, Rita*, etc.), snake head (*Shoil, Gazar, Taki*), live fish (*Koi, Singhi, Magur*, etc.) and small fish (*Mola, Dhela, Punti, Khoilsha*, etc.) The major stakeholders of aquaculture include fish farmer, hatchery owner, farm/hatchery technicians/workers, input (feed ingredient, fertilizer, hormone, chemical, instrument etc.) importers/suppliers, feed mill owners, homestead feed producer, fisher, fish processor, fish transporter, wholesaler, exporter, retailer, consumer, technology provider (government and non-government) and many more[92].

The aquaculture production both in fresh water and brackish water has significantly increased during the last two and a half decades with development of technology

Livestock production

Livestock is an integral component of the complex farming system in Bangladesh as it not only serves as a source of meat protein but is also a major source of farm power services as well as employment[93]. The livestock sub-sector provides full time employment for 20 percent of the total population and part-time employment for another 50 percent of the total population[94]. The poultry meat alone contributes a substantial 37 percent of the total meat production in Bangladesh. The GDP contribution of this sub-sector has been a modest 1.47 percent and the share of livestock in agricultural GDP is 13.62 percent[95]. Livestock species available in Bangladesh are the most versatile in relation to existing integrated agricultural farming system. About 24.5 million heads of cattle are distributed in Jamuna basin. About 85 percent of cattle are indigenous in origin and rest of them are *Red Chattogram*, *Pabna, North Bengal Grey* and *Munshiganj*[96].

About 98 percent households in Jamuna basin keep cows and population of cows is 3.3 per household. Buffalo and sheep in this area are very small in number. About 16 percent households keep goats with an average size of 2.9 per sheep keeper household[97]. About 33 percent of households are involved in semi-scavenger housing for goat, duck, and hen rearing as climate-resilient practice for livestock rearing in Jamuna basin.

About 2.90 million tons of meat and 4.23 million tons of milk are produced in Jamuna basin. The eggs produced from both local and commercial brides of poultry and ducks in this area are 46.56 million[98]. The dairy and poultry farms have grown rapidly in this area. Almost all rural households rear local poultry and ducks for their own consumption. Sometimes the housewife of a household sells excess poultry, duck and eggs for cash which is used for children's food and education expenses and to buy cosmetics and cheap ornaments.

Agriculture in northwest Bangladesh

Shahriar Wahid, Fazlul Karim and Mohammed Mainuddin

Water and agricultural livelihoods

In 1974, Bangladesh suffered its worst famine. Acute food shortages resulted in the mass starvation of millions. Successive governments targeted food self-sufficiency as their key strategic development goal. The outcomes have been most encouraging. Today, the country is mostly food self-sufficient[99] and one of the largest rice producers in the world. The noted positive achievement of the last few decades has been possible due to water and land management reforms such as widespread adoption of the minor irrigation system, liberalization of the water market, strengthening of extension services, and participation of private and government organizations.

However, climate and other environmental changes pose a major challenge to food self-sufficiency. Northwest Bangladesh is a case in point (Figure 11). The region is bordered by two major transboundary rivers - Ganges (called Padma River in Bangladesh) in the south and Brahmaputra in the east (called Jamuna River in Bangladesh) and part of the Ganges-Brahmaputra Basin. It produces thirty-five per cent of the nation's dry season rice and sixty per cent of wheat and maize[100].

Today Bangladesh is mostly food self-sufficient and one of the largest rice producers in the world

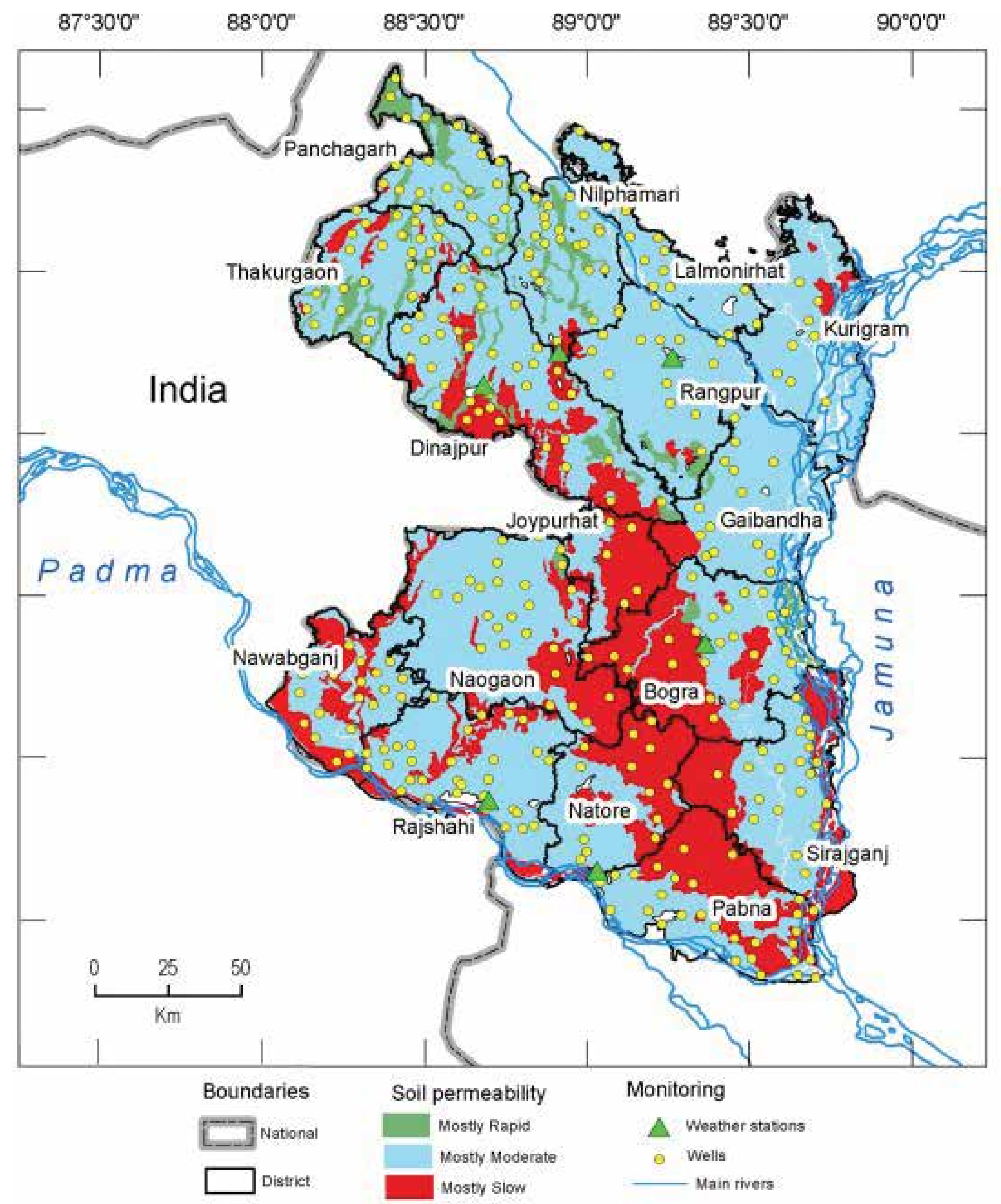
Challenges of declining surface water flow in rivers and groundwater table in recent times is a serious threat to the livelihoods of millions of farmers[101–102]. In severely dry years, many poor agricultural labourers seek to out-migrate from rural areas to bigger cities in search of better livelihoods options. Past mass internal out-migration of agricultural labourers from greater Rangpur region who did not get a job to survive during the *Monga* seasons[103] is well documented. Repeated episodes of such events can catalyse political unrest and social instability and their impact on rural livelihoods is a source of concern for Bangladesh. Here, we present a first-hand account of the irrigation trend and how it can sustain agricultural growth in the northwest region of Bangladesh.

Changing irrigation dynamics

Irrigation plays a crucial role in crop production in northwest Bangladesh. It scales down crop loss, allows multiple and high yielding variety cropping and reduces excessive dependence on rainfall. Both surface and groundwater were used for irrigation in the region. However, surface water availability in the major rivers of northwest Bangladesh started to decline three decades ago. Dey et al[104] reported that the yearly mean river water flow has reduced by about fifty per cent on an average in major regional rivers since 1980. The worst-hit districts are Dinajpur, Rangpur, Bogra and Rajshahi.

Shortage of surface water from rivers, ponds, and canals during the dry season forced the farmers to rely on groundwater to irrigate farmland, found within 4-8 meters below the ground surface, to cope with the intermittent surface water supply. The government

Figure 11. Geographic characteristics of northwest Bangladesh (Source: Peña-Arancibia et al. 2020)



of Bangladesh supported the farmers to adopt groundwater irrigation by lifting the restriction on irrigation pump standardization, allowing import and operation by the private sector and subsidizing farmers' energy consumption to lift groundwater. Strong institutional support was provided by several agencies including Bangladesh Agriculture Development Corporation and Barind Multipurpose Development Agency and large national projects like National Minor Irrigation Development Project under the Ministry of Agriculture. This has resulted in a drastic increase in the ratio of surface water and groundwater use for total irrigated agriculture in the last two decades. Today, about ninety-five percent of the irrigation water in northwest Bangladesh comes from groundwater[105]. Access to cheap groundwater has changed the cropping pattern markedly during the last decades in the region. Farmers grow more than two crops a year, with up to four crops in some areas. Peña-Arancibia et al[106] estimated a large increase in the area planted with Boro (dry season) rice (from 116,007 hectares to 1,598,105 hectares) and a large decrease in the area of the early wet season (Aus) rice (from 954,226 hectares to 225,190 hectares). Cultivation of Boro rice requires a higher amount of water and a longer period to irrigate compared to Aus crops and transition to Boro rice cultivation comes at the cost of substantially more irrigation. Additionally, farmers increasingly plant potatoes, wheat, maize, oilseeds and pulses during the dry season.

Unabated promotion and popularity of groundwater irrigation come at a price. The increasing extraction of groundwater for irrigation without any increase in rainfall has significantly lowered groundwater table of northwest Bangladesh especially in the districts of Rajshahi, Dinajpur, Bogra, Pabna and Rangpur. Rahman et al[107] observed that dry spells have become more frequent than ever before. The total annual rainfall over the region has been continuously reducing in the last three decades directly impacting aquifer recharge[108]. Farmers are not able to adequately irrigate their farmland due to increasing cost of lifting water from a deeper aquifer, and in some years even lack adequate drinking water during the dry season. Every year the groundwater table remains below the suction lift limit (6 meters) of the suction-mode pumps (e.g. shallow tube well) in sixty percent of the monitoring wells for about 3 to 6 dry season months[109]. Peña-Arancibia et al[110] analysed a large number of (over 1,200) groundwater monitoring well data collected by the Bangladesh Water Development Board and reported that during January 1980 to December 2015, groundwater table declined by 0.08 meters every year over the region. In three southern districts of Naogaon, Rajshahi and Nawabganj, the groundwater table fell by 0.2 meters every year. These findings are consistent with other researchers[111]. Another major reason for the lowering of the groundwater table is declining river flow in the major rivers. Though the surface water-ground water interaction is a complex process, water flows from the Jamuna River to the aquifer (rechange) are about five times higher than the water flows from aquifer to the river (discharge)[112]. The flow of the transboundary Teesta River is one of the major contributors to groundwater recharge in Dinajpur and Rangpur districts where predominantly silty clay soil has higher hydraulic conductivity[113]. River flow reduction in the major transboundary rivers of the Brahmaputra basin (Jamuna and Teesta Rivers) in Bangladesh will create more head difference for water to flow from the aquifer to the river thereby adding to the challenges to groundwater irrigation.

Sustainable irrigation management will require managing the two ostensibly distinct water sources as one

The falling groundwater table indicates large declines in groundwater storage over time and the northwest region lost about 3.74 km^3 of groundwater during 2003-2016[114]. Many planners and researchers fear that if groundwater extraction continues to increase in the future, it will push the groundwater levels down to such levels that it may not get replenished adequately and call to increase the use of surface water irrigation. Kirby et al[115] point out that excessive water withdrawal may cause a lower equilibrium level of groundwater aquifer and suggests local level studies to improve the sustainability of irrigation in the region.

Sustaining agricultural growth

Food self-sufficiency in northwest Bangladesh heavily relies on irrigation. Changing climatic condition such as reducing rainfall, increasing over-reliance on groundwater irrigation and reduction in transboundary river water flow pose serious challenges to planners and farmers alike. No single policy intervention and practice change will be adequate to face the challenge. Past water dynamics clearly highlight the importance of treating surface and groundwater as a hydrologically connected singular source of water and recognising that changes in either affect the other. Sustainable irrigation management will require managing the two ostensibly distinct water sources as one. The government will need to think about reducing irrigation demand through rationalizing less water demanding crops.

The Bangladesh Agriculture Policy[116], which called for the use of surface and groundwater to accelerate crop intensification and increase yield, is a move in the right direction. Efforts need to continue to accelerate and coordinate the activities of various agencies involved in surface and groundwater irrigation programmes and ensure river flows in the major rivers many of which are transboundary in nature. Markets need to be created for non-rice crops and agricultural extension services need to facilitate farmers' transition to less water demanding crops. Management approaches such as variable and/or crop-specific irrigation rates and efficient irrigation scheduling can play an important role in reducing demand. In an era of climatic extremes, planners and farmers will need to augment natural water supply through innovative technology as managed aquifer recharges. Transboundary water cooperation will play a crucial role to ensure waters in the rivers since many come across international boundaries from upstream.

Today, about ninety-five percent of the irrigation water in northwest Bangladesh comes from groundwater

TEA

Tibetan Tea

Xiawei Liao

TIBETANS DRINK butter tea every day. Butter tea is made by mixing butter that is made from yak or sheep milk with brick tea and salt. A typical Tibetan breakfast includes butter tea with *tsampa*, a Tibetan pancake made from highland barley flour. For Tibetans living a nomadic lifestyle with high-fat and low vegetable and low fruit diets, butter tea not only warms up the body against the coldness but also supplements the dietary fibers, helping to break down and digest the oil.

Butter tea not only warms up the body against the coldness but also supplements the dietary fibers. Yigong tea plantation is the highest tea plantation in the world

According to anecdotal evidence Tibetan monks started to grow tea trees between AD 220 to 280 but did not succeed due to the harsh climate. Modern tea plantations started in 1956 when the army based on Rima County planted 200 tea trees that survived and thrived. In 1971, Tibetan provincial agriculture and husbandry department imported 0.1 million kilograms of tea tree seeds from Sichuan, Yunnan and Hunan and sowed them in over 20 counties at altitude ranging from 1,570 to 3,700 meters above the sea level. Although most seeds did not survive the cold and harsh climate, tea plantations started to develop in several counties such as Chayu, Milin, Linzhi, Motuo and Bomi[117].

Currently, tea plantations[118] in Tibet are mainly located in the Yigong village of the Bomi county and Motuo county in the Nyingchi prefecture in the Southeastern part of the province. Yigong tea plantation is the highest tea plantation in the world. The plantation covers an area of 1.47 sqaure kilometers. In 2013, it produced 3,200 kilograms of Tibetan black tea, 3,600 kilograms of Nyingchi green tea, 900 kilograms of dark tea, 34,000 kilograms of brick tea and 3,000 kilograms of autumn tea. Since 2010, Motuo county has developed 13 highland organic tea plantations with a total area of 2.86 square kilometers. The main tea types are Fuding white tea, Ti kuan yin and pekoe.

From 1990 to 2017, the area of tea plantations in Tibet has increased from 149 to 790 hectares[119]. However, tea production in Tibet is not enough to support the population's tea consumption, therefore Tibet imports large amount of tea from other provinces in China, such as its neighboring Sichuan.

❄

Assam Tea

Pooja Kotoky

ASSAM IS the largest contiguous tea-growing area in the world[120]. Only those teas grown and manufactured in tea estates located in the Brahmaputra valley qualify to be called

Assam teas. Both Orthodox and CTC (Crush/Tear/Curl) varieties of tea are manufactured here. Assam Orthodox Tea is a registered Geographical Indication (GI). The distinctive second flush orthodox Assam teas are valued for their rich taste, bright liquors and are considered to be one of the choicest teas in the world. The Brahmaputra valley with its high rainfall, high humidity, and rich loamy soil provides the perfect environment for growing the tea that is most famous for its strong, smooth and malty taste. Half of India's tea production comes from Assam. The estimated annual average production of tea in Assam is about 630-700 million kilograms[121]. The Assam CTC tea auction centre is the world's largest, and the world's second largest in terms of total tea auctioned. The Tocklai Experimental Station, established in 1911, the world's oldest and largest research station of its kind, carries out clonal propagation and constant research in order to retain the flavours of Assam teas.

Assam is the largest contiguous tea-growing area in the world. The Assam CTC tea auction centre is the world's largest, and the world's second largest in terms of total tea auctioned

History of tea in Assam

The tea industry in Assam is about 172 years old. In 1823 Major Robert Bruce discovered wild tea plants growing in Assam with the help of a local noble man, Maniram Dutta Borua 'Dewan' in an adventure and trade trip to Upper Assam by boat. Maniram Dewan introduced Bruce to Singpho Chief Beesa who presented Bruce his first bowl of wild tea found in the Singpho village near Margherita in Upper Assam. Bruce made an agreement with the Chief to supply some plants and seeds. In the following year Singpho Chief kept his commitment by handing the plants and seeds to Major Robert Bruce's brother C.A. Bruce who visited Sadiya town. Later these were sent to Dr. N. Wallich, botanist to the East India Company and Superintendent of the Botanical Garden in Calcutta.

In 1834, Lord William Bentinck the Governor-General at that time, set up a tea committee to explore and discover new land for tea cultivation in India. The Tea Committee received communication and reports from Col. Jenkins, the then Commissioner of Assam that the tea plants found in Assam were of indigenous variety. The following year a scientific committee proceeded to Sadiya for research. They ascertained that the tea plants found in the North Bank of Brahmaputra were of indigenous kind and there was great similarity in the topography and the climatic conditions to that of the Chinese province of Yunnan, which was known for tea production.

C.A. Bruce travelled through the length of the Brahmaputra valley and along Buri Dihing river, and discovered wild tea grown in places such as Phakial, Tingri near Indo-Burma boarder. With his knowledge of languages and mannerism of the natives he became instrumental in establishing friendly relations with the hill tribes and their chiefs and transferred forests and waste lands from the tribals to the British Government. Bruce started plantations at Jaipur and Chabua with the local tribes and set up nurseries at Chota Tingrai and Hukanpuki to have large plantation drives by 1840.

In order to streamline business operations in Assam and import tea to London, in February of 1839 Bengal Tea Association was formed in Calcutta and a joint stock company – Assam Company was formed in London. Both the companies were amalgamated as the Assam Company within the year and became the first private owned tea company to operate in Assam. Initially the company made losses because of the high cost of production but started recovering and profiting from 1848. In March of 1841 the first auction sale of Assam tea manufactured by Singpho Chief Ningrula and the Government plantation took place in Calcutta. Sensing opportunities a number of private enterprises approached the Government in London and Calcutta to obtain tea plantations.

Currently, the tea plantation is the largest employer among the organized sector in Assam, employing about more than 6.86 lakh persons daily

The tea industry started to change after 1850s when George Williamson Senior and his cousins formed Williamson, Magor & Co in 1853 and started private plantations. They produced 21,000 kgs tea in 200 acres land in 1857. By 1859 there were 160 gardens, 57 were privately owned and rest by Assam Company, the Jorehaut Tea Company, The East India Company, the Lower Assam Tea Company and the Central Assam Tea Company.

Although the tea industry has gone through many ups and downs over the years in terms of financial stability, price fluctuations, changes in demand and supply, great improvements have also been made in the yield per acre, in the grouping of gardens under a limited number of companies, in the progressive mechanisation and rationalisation of production and in increasing their efficiency in regard to the productivity of labour[122]. Modernisation of factories and production techniques also took place. The Indian Tea Control Act,1933, was enacted and an International Tea Committee and Indian Tea Licensing Committee were instituted.

Present scenario

Currently, the tea plantation is the largest employer among the organized sector of the state, employing about more than 6.86 lakh persons daily[123]. Although an almost equal number of female and male employees work in these plantations, female labour is largely employed to pluck tea leaves, while male employees work in maintenance of estates (including pruning), factory work, pesticide application and weed removal. Women are often paid lower wages than men.

A sizable number of small farmers especially in upper Assam have taken up tea cultivation during the last 15 years. As per 2016[124] data, out of the total number of tea gardens, there were 84,577 small growers with a total area of 78,203 hectares under tea cultivation, and 767 big growers with a total area of 226,197 hectares under tea cultivation. Total tea produced in 2016 was 642,180 (000) kgs. As of 2017-18, 676,000 tons of tea leaves were produced in 312,000 hectares of land which accounted for 51.7 percent of the total national production of India.

The relative contribution of small growers to tea production is more than 20 percent[125] and the big gardens purchase a major part of the green leaf production of the small tea growers. Using clone varieties of tea seedlings on small holdings, these small and marginal farmers are dependent on their crop as the main source of income. Although these farmers are challenged by low farm gate prices, limited market channels, poor access to credit and low levels of farmer organization, the positive aspect of lower production costs is what keeps them going. Some small tea growers have ventured into organic tea cultivation[126].

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AGRICULTURE ON THE *CHARS*

Brahmaputra valley

Vasudha Pangare

Chars or riverine islands formed by the braiding of the Brahmaputra river, keep changing in shape and size due to the effect of floods and erosion

CHARS OR riverine islands formed by the braiding of the Brahmaputra river, keep changing in shape and size due to the effect of floods and erosion. Many of the *chars* remain stable long enough for vegetation to grow and for settlements to establish. Islands which are stable for a decade or more are generally utilized for growing horticulture and plantation crops, and islands which are relatively less stable are used for growing short duration seasonal crops such as vegetables. A majority of these *chars* remain fallow and unutilized. Even in the case of *chars* used for cultivation, agricultural land keeps changing during the entire crop cultivation season from sowing to harvesting.

The total area of vegetative *chars* has increased in the past three decades in the Brahmaputra Valley and approximately 146 thousand hectares area[127] of *char* lands have been stable for the past ten years. Two crops are cultivated during the non-flooding months from November to April on *chars* in the Lower Brahmaputra Valley. Crop cultivation is almost negligible compared to the large size of the islands, in the Upper Brahmaputra Valley, as the *chars* here are less stable. In the Central Brahmaputra Valley, seasonal migration of *char* dwellers occurs for crop cultivation; *char* dwellers do not have settlements here.

Jamuna Basin

Kshirode Roy

CHAR LANDS of Bangladesh have a good potential for increasing agricultural production. The country has about nine million hectares of total cropped land, which is decreasing at the rate of 0.73 percent per year due to housing, roads, industries and other infrastructure development. On the other hand, the total area of *chars* of four big rivers Padma, Meghna, Jamuna and Brahmaputra and their 500 branch-rivers and tributaries is about one million hectares, and is increasing every year. The Bangladesh government has given special emphasis on increasing agricultural production in *char* areas to reduce the vulnerability of disadvantaged people living there. *Chars* in Kurigram, Jamalpur, Gaibandha, Bogra and Sirajganj districts have a population of about 6.5 million people of whom 2 million are extremely poor. In general, Kurigram district is considered as the poorest district of the country.

Char dwellers largely depend on crop agriculture, fishing and livestock-rearing for their livelihoods. *Char* soils are predominantly loamy sand, loam and sandy loam. These are deficient in most of the plant nutrients, have very low organic matter content and minimum water holding capacity. Generally local crop varieties having very low yield potential are cultivated in these areas, therefore, the average yields are lower than the national average yield. However, high yielding variety seeds of *boro* rice, wheat, maize, vegetables and some other crops are grown by many farmers.

Char lands of Bangladesh have a good potential for increasing agricultural production. Char dwellers largely depend on crop agriculture, fishing and livestock-rearing for their livelihoods

The main crops grown in the *kharif I* season (mid-March to mid-July) are *aus* rice, jute and sesame. In the *kharif II* season (mid-July to mid-November) *aman* rice is grown and in the *rabi* season, *boro* rice, wheat, maize, mustard, chilli, onion, groundnut, potato, sweet potato and vegetables are grown. The irrigation facilities in *char* lands are very limited and used mostly for *boro* rice and to some extent for wheat and vegetables. Generally electric connection is not available in those areas; farmers have to use diesel engines for operating pumps. The price of diesel in *char* areas is higher than on the mainland. Therefore, the cost of irrigation and ultimately the production cost in *char* areas is higher than on the mainland.

Common vegetables grown in the *char* lands are pumpkin, cucumber, radish, brinjal, and pointed gourd. Farmers can make more profits from vegetables than from rice, jute or sesame. Therefore, more farmers produce vegetables. Many of the farmers of the major milk producing district of Sirajganj are currently producing Napier grass along with vegetables. They grow this quick-growing grass for sale as well as for using it as feed for their cattle for increasing milk production and for fattening.

Flooding is a common phenomenon from mid-June to September. Late sown *aus* rice and *aman* rice are mostly affected by floods. However, due to huge sedimentation and carbon influx, flooded soils remain fertile. When devastating flood occurs, houses of

First year of agriculture on a newly formed char

Agriculture being stabilized on the char during the second and third year

Fully developed agricultural fields on the char after 5 to 8 years most *char* dwellers are damaged. Farmers living there have to take temporary shelter on unsubmerged roads and even have to move to slums of towns and cities and return after the flood recedes. Some of them taking shelter in towns and cities do not return to the *chars* and find new ways of earning their livelihood.

Farmers of *char* areas do not usually practice modern agricultural technologies like mainland farmers. Modern technologies need costly inputs like high yielding variety seeds, fertilizers of both macro and micro-nutrients, and pesticides, all of which poor farmers of *char* areas cannot afford. As most farmers cannot mortgage lands, they cannot get loans from banks. Because of transport problems, price of seeds, fertilizers, pesticides, etc. are costlier than the mainland. Farmers make very little profit from selling their produce because the input costs are higher. Primary education, health and agriculture extension services and support to cope with natural calamities, like flood and soil erosion are minimal.

To increase crop production in *char* areas, government and nongovernment organizations have implemented many programmes to increase annual incomes and improve the livelihood of farmers. These programmes include activities such as demonstration of modern agricultural technologies, training of farmers on improved crop production, primary education, health care, improvement of infrastructure, activities for the empowerment of women, all of which contribute directly and indirectly to agricultural and livelihood improvement. In recent years, research institutes have implemented many programmes to introduce high yielding varieties in *char* areas through on-farm demonstrations. Depending on agro-ecological zones, different technologies have proved appropriate in different *chars*, many of which have been adopted by farmers and increased crop production. For example, a farmer of the Brahmaputra Char has spent Tk 18,000 (approximately USD 212) on an average for cultivating pumpkin on 200 raised sandbars and sold them at Tk 42,000 (approximately USD 495.5). He made a net profit of Tk 24,000 (approximately USD 283) in one cropping season.

Hand percussion (sludger) or hand drilled shallow tube-wells are a common source of groundwater on the chars of Bangladesh

Many NGOs and international organizations have implemented programmes to support women's participation in agriculture development and have ascertained that women have increased their access to new knowledge on modern agriculture. Women who participated in these programmes are able to produce better quality products, maintain better quality seed through better storage facilities and have access to product marketing. As these women have increased monetary contribution in the family, they are able to provide better food and clothing to their children and invest in their education and health care. In general, the average benefit cost ratio of crop farming with GO-NGO supported programmes is more than that of un-supported programmes.

As an outcome of various programmes, agricultural production has increased, and livelihood has improved for *char* dwellers. These can further be improved if transportation and communication facilities are improved, government social safety net programmes are enhanced and compulsory primary education programmes for boys and girls are implemented.

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Hand-dug tube-wells

Md Hossain

HAND PERCUSSION (sludger) or hand drilled shallow tube-wells are common sources of drawing groundwater on the chars of Bangladesh. This technology can tap groundwater from a depth up to 7 meters below the surface and can be used effectively in soft sub-surface sediments comprising mostly of sand and clay.

A drilling derrick is constructed with local bamboos. The main crew continues the hand-chopping on the boring pipe, while other crews exert pressure on the boring pipe by means of a hand-driven lever, made of bamboos and/or pipes. A small pit is made near the derrick in which locally available clay and water is mixed to make drilling mud. Conventionally drillers used cow-dung, which is being strongly discouraged due to its impact on water quality. A steel pipe is used for the uppermost 2 meters section, on the top of which the hand pump is installed and the remaining portion consists of PVC pipe.

The diameter of the tube is most commonly 0.4 meters (1.5 inch). Number 6 Hand Tubewell, a lever operated suction pump, is generally used. Once the tube-well is installed, continuous pumping is done for a reasonable time so that the well becomes free from drilling mud. The cost of installation of a shallow tube-well of 100 meters depth, could be around 20 thousand Bangladesh Taka (approximately 250 USD).

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