Climate resilient agriculture in Manipur: status and strategies for sustainable development

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Manipur in India is endowed with rich biodiversity and abundant natural resources. Despite inaccessibility, marginality and heterogeneity, the state has made good progress in agriculture and allied sectors. About 80% of the state population depends on agriculture for livelihood. However, agriculture sector in Manipur is facing the consequences of climate change. Climate change is a reality and an increasing trend in temperature, precipitation and emission of greenhouse gases has been observed in Manipur. The state is also projected to experience more of extreme rainfall and reduction in crop yields. As subsistence level farming is coupled with prevalent shifting cultivation, the small and marginal farmers will be most affected due to climate change. Hence, there is an urgent need for devising climate proof plan and climate ready policy for climate compatible agricultural development in Manipur. Location-specific climate smart technology baskets need to be devised or introduced and should be demonstrated through participatory approach, for ensuring a climate resilient production system, and a climate resilient ecosystem. The interactions between the system's adaptation strategies and the mitigation potential should also be given due importance in the action plan for combating climate change. This article deals with the present status of agriculture and allied sector and various technological and policy options for climate resilient agriculture in the hill and mountain ecosystems of Manipur.

Keywords: Climate smart agriculture, climate change, Northeast India.

MANIPUR is nestled in the northeast corner of India. It is bound by Myanmar (Burma) on the east, Nagaland on the north, Assam on the west and Mizoram on the south. The state lies between 92°58′E and 94°45′E long. and 23°50′N and 25°42′N lat. Altitude varies from 40 m (Jiribam) to 3114 m (Mount Iso) amsl. The hill and valley terrains in the state represent a distinct geographical entity. The central valley region is surrounded by hills all around along with isolated hillocks. The north and south analogous ridges represent an alignment of hill ranges. Compared to the western aspects (1800–2500 m amsl), the eastern aspects (800–100 m amsl) of hilly terrains are more elevated. According to the 2011 census, the state's population is 27.21 lakhs with a sex ratio of 987 and literacy rate of 79.85% (Table 1).

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Status of agriculture and allied sectors

The major geographical area of the state (22,327 sq. km; 90%) is hilly (5 districts) and the rest is central valley (4 districts). The size of cultivated area is about 10.46% of the total geographical area. Agriculture is characterized by rugged terrain, wide variations in slopes and altitude, community land systems and conventional cultivation practices. The pace of economic growth and development has been good (Table 2) but there is scope for further development.

Agricultural production system is mostly rainfed, monocropped and at subsistence level. Use of local varieties, limited use of agro-chemicals (especially in hills), low moisture retention capacity of upland soil and lack of irrigation facilities along with traditional management practices have resulted in low crop productivity and low cropping intensity. Problems of high rainfall (12.10% of the country's total precipitation), soil acidity, aluminum toxicity in upland and iron toxicity in the valley have added to the problem of low agricultural productivity in the north eastern region of India. The hilly area is characterized by red ferrogenous soil types, whereas alluvium covers the valley. The steep hilly slopes are vulnerable to sheets and gullies erosions, resulting in barren rocky slopes. There are four major soil order found in Manipur namely entisol, inceptisol, alfisol and ultisol. In general, soil fertility status is low to medium. Soil nutrient analysis of more than 2070 soil samples collected from 690 locations (0–15 cm depth) covering all 9 districts is presented in Table 3.

Table 1. Brief demographic and economic scenario of Manipur[41]

Demography	Geographical area (ha)	Population	Growth rate (%)	Sex ratio	Literacy (%)	Density (population/km^2)	Land : man ratio
2011 Census	2,232,700	2,721,756	18.65	987	79.85	122	0.82

Table 2. Economic status of Manipur[42]

Economy (2012–13)	Current prices	Growth over previous year (%)	Constant (2004–05) prices	Growth over previous year (%)
Gross State Domestic Product (GSDP)	11,713	12.52	8,073	7.14
Net State Domestic Product (NSDP)	10,436	12.47	7,248	7.17
Per Capita Net State Domestic Product	36,290	10.42	25,205	5.23

Table 3. Average soil nutrient status of different districts in Manipur

Districts	Value	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Bishnupur	Maximum	6.12	3.21	712.40	71.30	213.57
	Minimum	5.90	0.58	125.00	8.60	83.60
	Average	5.41	2.20	268.95	49.95	154.63
Chandel	Maximum	6.34	3.03	439.00	90.70	431.00
	Minimum	4.67	1.25	188.00	1.60	43.00
	Average	5.38	2.35	341.90	18.83	190.67
Churachandpur	Maximum	6.42	3.78	631.00	58.00	627.00
	Minimum	4.88	0.80	23.00	7.10	112.00
	Average	5.43	2.09	443.43	14.14	418.43
Imphal East	Maximum	6.84	2.70	924.00	47.00	401.00
	Minimum	5.14	0.27	216.00	1.50	22.00
	Average	5.56	1.15	474.17	11.20	94.08
Imphal West	Maximum	6.89	3.60	942.00	35.00	902.00
	Minimum	4.06	0.34	112.00	4.80	12.50
	Average	5.37	1.31	378.13	10.86	179.95
Senapati	Maximum	6.49	6.90	674.00	294.80	1276.00
	Minimum	4.62	0.63	35.00	4.70	19.00
	Average	5.51	3.39	262.19	25.35	361.43
Tamenglong	Maximum	5.66	2.41	251.00	30.10	624.00
	Minimum	4.61	1.09	63.00	21.60	97.00
	Average	5.01	1.62	148.00	27.04	381.00
Thoubal	Maximum	6.60	4.29	407.68	140.83	401.00
	Minimum	4.81	1.01	212.00	5.70	150.08
	Average	5.34	2.54	282.84	63.40	301.65
Ukhrul	Maximum	6.12	4.05	924.00	73.6	978.00
	Minimum	4.53	0.36	94.00	2.30	88.00
	Average	5.39	1.70	429.67	11.34	330.54

About 80% of the state population is engaged in agriculture and allied activities. Hence, agriculture plays an important role in the social and economic life of people in Manipur, and will continue to do so in the foreseeable future. The gross cropped area is ~350,290 ha, which account for ~15.24% of the total land areas (Table 4). About 65.93% of the gross cropped area is under rice cultivation. The tribal population of the hills practices *jhum* cultivation. The mean cropping intensity of the state is 145.66%. The annual seed replacement ratio varies from 0.75% to 1.0% only. However, fertilizer consumption during 2014–15 was 31.75 thousand tonnes. The total food grain production in Manipur during 2014–15 was 594.28 thousand tonnes from an area of 292,950 ha[1]. Paddy is the major crop with a productivity of 2.23 tonne/ha.

Horticulture plays an important role in subsistence farming which is practised by majority of the small and marginal farmers, especially in hilly districts. The state is bestowed with several pre-requisites for successful cultivation of horticultural crops. The major fruit crops are pineapple (*Ananas comosus*), banana (*Musa* spp.), passion fruit (*Passiflora edulis*), khasi mandarin (*Citrus reticulate*) and kachai lemon (*Citrus jambhiri*). Recently temperate fruit crops like kiwifruit (*Actinidia deliciosa*) and plum (*Actinidia deliciosa*) have gained popularity.

Almost all kinds of vegetables can be grown, however, cole crops, legumes (broad bean (*Vicia faba*) and rice bean (*Vigna umbellate*) and cucurbitaceous crops are mostly preferred. Some indigenous vegetables like tree bean (*Parkia roxburghii*), water momosa (*Neptunia oleracea*), leek (*Allium porrum*) and chinese chive (*Allium tuberosum*) are popular among people. The major spices are turmeric (*Curcuma longa*), ginger (*Zingiber officinale*) and chilli (*Capsicum* spp.). Manipur is known for king chilli (*Capsicum chinense*), one of the hottest chillies in the world. Moreover, Manipur is a treasure trove of many underutilized and indigenous horticultural crops, some of them are rich in bioactive properties and are used in traditional and ethnic medicines. But, horticulture sector remains unexploited commercially. The total area under horticultural crops was 100.01 thousand hectares in 2014–15 with a production value of 1159.03 thousand tones (ref. 2) (Table 4).

Animal husbandry and poultry rearing are integral allied agricultural enterprises in addition to agri-horti production systems. The small and marginal farmers of the state, in general, earn their gainful employment from this sector with cattle, buffalo, sheep, goat, mithun, pig, etc. representing the main categories of the animals being reared. Rearing of pigs and poultry are important sources of income, especially in the hills. There was a decrease in livestock population over 2007 to 2012 from 0.78 million to 0.69 million registering a decline of 11.76% in the total number of animals of various species[3]. During 2013–14, the state produced 81.70 thousand tonnes of milk, 1165.31 lakh number of eggs and 18.22 thousand tonnes of meat[4].

Fish is one of the major food items consumed by the people of Manipur. The largest source of fish is Loktak lake (230 sq. km surface area) in Bishnupur district. Presence of water bodies like ponds, natural lakes, rivers, reservoirs, low lying paddy fields, etc. signify the vast and untapped potential of this sector. The total water area in Manipur shrunk from around 1 lakh hectares in 1990 to around 56.46 thousand hectares in 2009–10. The state produced 28.54 thousand tonnes of fish and more than 125 million fish seed in 2013–14 (ref. 5).

Table 4. Area, production and productivity of major crops in Manipur (2014–15)[1,2]

Crops	Area ('000 ha)	Production ('000 t)	Productivity (t/ha)
Agricultural crops (2014–15)			
Paddy	224.38	501.16	2.23
Maize	36.19	58.75	1.62
Pulses	30.22	28.75	0.95
Oilseed	36.69	31.68	0.86
Wheat	2.16	5.62	2.60
Sugarcane	5.85	339.31	58.00
Potato	14.80	125.42	8.47
Total	350.29	1090.69	3.11
Horticultural crops (2014–15)			
Fruits	55.63	533.60	9.59
Vegetables	27.77	297.73	10.72
Spices	15.78	144.38	9.15
Flowers	0.81	183.30	226.30
Plantation crops	0.03	0.02	0.64
Total	100.01	1159.03	11.59

Climate change and regional food security scenario

Manipur has been affected by the changing climate. Trend analysis of weather variables in Imphal under National Innovations on Climate Resilient Agriculture (NICRA) revealed that the mean annual maximum temperature (1954–2014) has been increasing (0.1°C per decade) (Figure 1). The mean annual minimum temperature has also increased significantly (0.3°C per decade). The total annual rainfall (Figure 2) recorded during the period 1954 to 2014 also increased (23.5 mm per decade); however, a decreasing trend was observed in February, June, July and November rainfall (–10.8 to –0.1 mm per decade). The mean annual rainy days (1954–2013) showed an increasing trend. Decreasing trend in total monthly rainy days was observed in January, February, April, June and July. The mean annual maximum relative humidity (RH) increased significantly (3.8% per decade) from 1985 to 2013, whereas the mean annual minimum RH (1985–2013) showed a decreasing trend (–1.6% per decade). The mean monthly maximum RH increased significantly (3.0–5.6% per decade) throughout the year. Similarly, decreasing trend was observed in mean monthly minimum RH (–3.2% to –0.6% per decade) for all months except May (1% per decade). The trends of annual temperature and rainfall in Imphal region are presented in Figures 1 and 2 (ICAR Research Complex for NEH Region, Manipur Centre, 2015).

Temperature is projected to rise by over 1.7°C by the end of 21st century[6]. The southern districts are expected to experience higher temperature than that of the northern districts. Total annual precipitation is expected to increase throughout the state. As evident from the last 30 years' climate data analysis, precipitation rate in northern parts is expected to increase by ≥19%. The northern districts like Tamenglong and Senapati are expected to receive ≥21% precipitation as compared to southern districts (≥15%). It is also projected that the extreme rainfall events (100 mm/day) will become more frequent. Crop yields are projected to decrease by 10% in 2030. Greenhouse gas emissions have also increased in Manipur from 1980 to 2005 in terms of CO_2 (2274 Gg/year rate of increase with 3.85% CGR), CH_4 (0.419 Gg/year rate of increase with 0.85% CGR) and N_2O (0.008 Gg/year rate of increase with 8.49% CGR)[7].

Extreme precipitation events will cause crop yield variation. Increase in pest and disease incidence as well

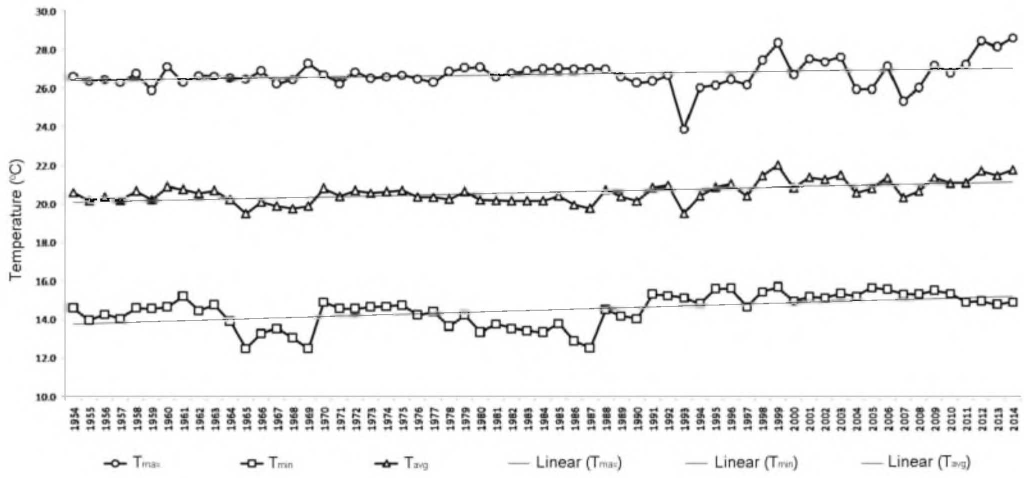

Figure 1. Annual temperature of Imphal Region, Manipur (1954–2014).

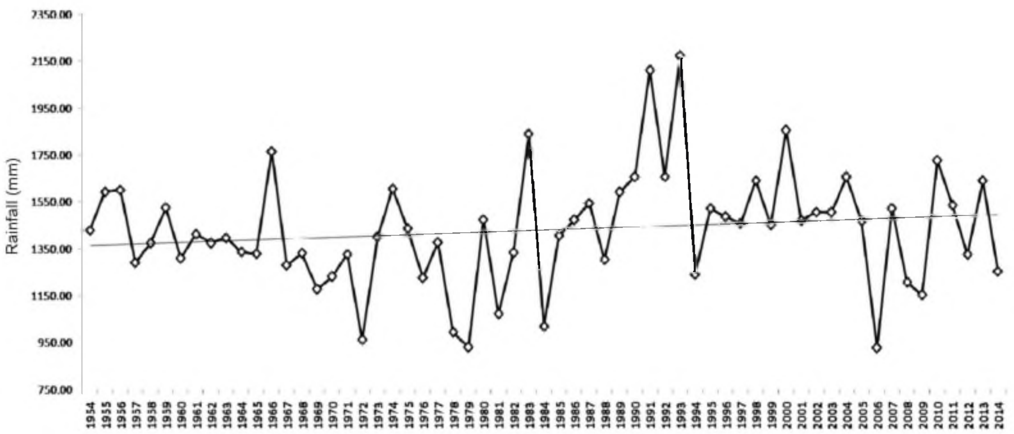

Figure 2. Annual rainfall of Imphal Region, Manipur (1954–2014).

as erosion and degradation of soil is also expected. Projected increase in evaporation and runoff will decrease the soil moisture recharge. Fresh drinking water could also become scare. With rise in surface temperature, the plant species are expected to move upward. Decrease in microbial population is projected with increase in altitudes. Loss of vegetation could cause top soil erosion. Loss of bio-diversity and extinction of rare/threatened flora and fauna are also projected. Food grain production and requirement of the state have been estimated to be 77105 and 79323 thousand tonnes by 2050. Hence, Manipur will be in deficit of 2218 thousand tonnes of food grain by 2050 (ref. 8).

Natural resources in changing climate

Manipur has abundant natural resources, viz. soil, water, forest, etc. The environmental sustainability index (ESI) is very high (100.00) and was ranked 2nd in India during 2011 (ref. 9). Loktak lake, the largest freshwater lake in north east India, is located in Manipur. There are four major river basins namely the Barak river basin (9041 sq. km catchment area) in the west, the Yu river basin in the east, the Manipur river basin (6332 sq. km catchment area) in the centre part and a portion of the Linyi river basin in the north. The total water body in the state covers an approximately 56.46 thousand hectares. However, the hydrological system has been altered due to climate change and human pressure.

An area of 1699.40 thousand hectares is under forest cover[10]. With seven types of forest class, viz. tropical semi-evergreen forest, moist deciduous forests, east Himalayan wet temperate forests, sub-Alpine forests, grassy blanks, bamboo brakes and cane brakes[11]. However, the state is vulnerable to soil erosion due to its undulating topography, steep slope and high rainfall. Approximately 2190 thousand hectares have been classified as eroded area. Deforestation and practice of jhum cultivation accelerated erosion. It was reported that about 1189 thousand hectares of the state comes under different soil loss classes under water erosion (>10 t/ha/year), 2232 thousand hectares area comes under degraded and wasteland category and 1597 thousand hectares is affected by soil acidity[12].

Genetic agro-biodiversity

Manipur is one of the mega biodiversity hotspots in the world and has a treasure trove of various flora and fauna. The hilly terrains have diverse kind of forest (deciduous) and ground is covered with bushes, shrubs, grasses and other mixed vegetation. Bamboo forests are mainly found in the gentle hill slopes. Out of 126 taxa of bamboos reported from India, over 53 species are from Manipur[13]. In dwarf bamboo, the elevated CO_2 significantly increased the net photosynthetic rate, intrinsic water-use efficiency (WUEi) and carbon isotope composition (δ^{13}C) and decreased stomatal conductance (gs) and total chlorophyll concentration based on mass (Chlm) and area (Chla). Specific leaf area (SLA) was decreased with elevated CO_2. Elevated CO_2 also increased foliar carbon (Ca) and nitrogen concentration based on area (Na) and carbohydrates concentration. Together the elevated CO_2 and temperature did not affect SLA, Ca, Na, Chlm, and Chla. At elevated CO_2 level, dwarf bamboo did not show any occurrence of photosynthetic acclimation and was able to acclimatize physiological and morphological behaviours in terms of capturing more light, thus resulting in increased water use efficiency and nutritional status[14]. Hence, bamboo should be considered a potential component in climate change action plan.

Manipur has a rich genepool of primitive cultivars and land races of various agri-horticultural crops. There are enormous genepool of rice (more than 269 local varieties and land races), maize, cucurbits, legumes, tuber crops, turmeric, ginger and chillies. It has many underutilized fruits and vegetable crops, medicinal plants and flowering plants especially orchids. More than 500 orchid varieties covering 69 genera and 249 species have been reported[13]. Shirui lily (*Lilium mackliniae*) is a rare Indian species of terrestrial lily which is found only in the upper reaches of the Shirui hill in Ukhrul district.

The biodiversity in medicinal plants is an important floral wealth of the state. More than 1200 species of medicinal plants and the local medicinal uses of about 430 species have been documented. Manipur is also blessed with abundant wild relatives of cultivated plants, such as *Alpinia*, *Alocasia*, *Amomum*, *Mucuna*, *Pyrus*, *Prunus*, *Rubus*, etc. Wild species of banana namely *Ensete glaucum*, *Musa cheesmanii*, *M. magnesium*, *M. balbisiana*, etc. are abundantly found in Manipur. The Citrus family is represented by *Citrus reticulata*, *C. jambhiri*, *C. medica*, *C. indica*, *C. macroptera*, *C. maxima*, *C. latipes* and other species, etc. Fibre crops like *Crotalaria*, *Bauhinia*, *Cannabis*, *Sesania*, *Corchorus*, *Butea* and their varieties are also found in Manipur. Important forest trees are *Laurus*, *Melia*, *Bauhinia*, *Dillenia*, *Lagerstroemia*, *Terminalia*, *Gmelina*, *Bombax*, *Michelia*, *Schima*, *Gmelina*, *Podocarpus*, *Tectona*, *Dipterocarpus*, *Melanorrhoea*, *Quercus*, *Magnolia*, *Acer*, *Prunus*, *Pyrus*, *Ligustrum*, *Taxus*, *Bucklandia*, *Castanopsis*, etc. Over 20 species of gymnosperm and more than 300 species of Pteridophytes flora have been reported from Manipur. Different species of mushroom are also found in forest areas. More than 50 species of fleshy fungi, 121 algae and a few moses have been reported. According to the India Biodiversity Portal, out of 75 endemic plants of Manipur, 27 native plants have been classified as rare, endangered and threatened[13].

The impact of climate change on these horticultural crops is of high relevance. Shortening the growing period, decrease in water availability and poor vernalization are expected to decrease potential yields. Vulnerability, rarity and rapid extinction of plant species will be among other consequences[15]. Plants requiring high humidity and water may face challenges for survival. Due to changing climate, high temperature conditions are expected to be prevalent throughout the growing period which will increase temperature stress on the crops. This can disturb the biochemical reactions in plants essential for normal cell function. The photosynthetic functions of higher plants will be affected adversely[16]. Due to rise in temperature, crops tend to develop rapidly and mature early. For example, grapes, citrus, melons etc. will mature by about 15 days earlier. Specific chilling requirements of stone and pome fruits will be affected which may lead to early breaking of dormancy. Banana cultivation may suffer from high temperature, soil moisture stress or water logging[15]. Worldwide, environmental stress is one of the primary causes for crop losses, and can reduce average yield by more than 50%. The response of plants to environmental stresses is mediated by the developmental stage as well as the severity and length of the stress. To avoid one or more stresses, plants may respond similarly through morphological or biochemical mechanisms. However, the response can become more complex due to environmental interactions. High summer temperature can impair reproductive growth, yield and quality in different vegetables; while high winter temperature limits the cold hardiness and thus, hampers the seed production[16]. With increasing temperature under climate change scenario there would be changes in growing degree days (GDD), which has direct relation with phenology of the crop[17].

Pollination is crucial for reproduction of most flowering plants[18]. Climate change may reduce the activity of pollinating agents and pose a serious threat to pollination services[19–21] which may lead to floral abortion[22]. Climatic fluctuations are also known to affect post-harvest quality of vegetables and affect food safety during storage[23]. Climate change and CO_2 concentration is likely to alter key interactions between horticultural plants and pollinators, insect pests, diseases and weeds[17].

Melting of ice cap in the Himalayan regions is likely to reduce the chilling requirement for flowering plants, especially orchids. This may result in less abundant flowering or no bloom, while some other plants will be threatened. Commercial open field production of flowers will be affected severely and will lead to improper flower development, poor flowering and colour development[15].

Climatic factors like rainfall and extreme temperature, that are beyond the tolerance capacity of a species, may lead to inevitable distribution changes[24]. Evidences show that many plant species shift their geographical habitats to combat regional climatic variation[25]. Many species are unable to acclimatize to the pace of climatic variations. Stability in environmental conditions is essential for alpine regions, where many species may disappear altogether. So, these changes may increase the extinction risk[26].

Climate change alters water availability and the resulting water stress may affect crop productivity[16]. Particularly, under rainfed ecosystems, altered climatic conditions can expose crops to drought like situation[27]. Succulent vegetables will be drastically affected under low water regimes[28].

If atmospheric CO_2 concentration is doubled, the overall growth of C3 plant will increase, thus, resulting in increased marketable yield (30–40%)[29]. But the positive impacts of increased CO_2 concentration will be nullified by increased temperature and scarcity of water resulting in decreased production[30]. In this context, the indigenous fruit trees and agro-forestry species are expected to play a crucial role in increasing resilience of the hill ecosystem under changing climate.

About 31 endemic mammals have been reported from Manipur. Of these, 20 mammals come under rare and endangered class. Cattle, buffalo, sheep, goat, pig and dog are the major livestock enterprise here. The state is also known for indigenous breeds of horse and pony. Approximately 73 different types of birds, including 10 rare and endangered birds, are also found in the state[13] along with 8 species of silkworm. Manipur has more than 200 fish species and 139 ornamental fish species. Of these, 30 species are vulnerable, 15 are endangered and 3 are critically endangered. Indigenous fishes like *Bangana dero*, *Semiplotus manipurensis*, *Garra manipurensis*, *Osteobrama belangeri*, *Puntius manipurensis*, *Parambasis waikhomi*, *Lepidocephalichthys irrorata*, *Pangio pangia*, *Mystus ngasep* and *Glyptothorax manipurensis*, etc. are the few important members of Manipur fishery.

This extensive biodiversity of Manipur can provide basic building blocks for future food security in the form of climate resilient technologies. Conservation of this large genetic diversity and its sustainable use in future will help ensure food and nutritional security issues. The biodiversity conservation has to be correlated with sustainable agricultural development and food security[31]. Even though scientific and sustainable management of biodiversity resources has become one of the prime issues in Manipur, there is a wide gap in biodiversity management and conservation. As a result, many floral and faunal wealth are now on the verge of extinction.

Technological options for climate resilient agriculture

Technological intervention for climate smart agriculture (CSA) is an integral part of the local climate change action. Soil, water, nutrient, energy and genetic resources conservation and management and farming system, value chain and risk and uncertainty management and social safety nets are nine broad domains of CSA. For this, 'climate ready technology basket' needs to be developed through convergence of these domains. For climate change adaptation, sustainability attributes of agroforestry is considered a strong asset while for climate change mitigation, carbon sequestration by trees is significant. Agroforestry, especially leguminous and multipurpose trees, should be included in the farming system. Conservation agriculture with trees, also called as 'evergreen farming system' is another option for increasing the resilience of agricultural system[32]. Similarly, perennial horticultural crops can play an effective role in climate change adaptation and mitigation.

Pathak[33] suggested climate-ready crop varieties, changing planting date, growing resistant/tolerant crops varieties, conservation agriculture, intensifying crop production, intercropping/mixed cropping, organic farming, integrated farming system (IFS), integrated pest and disease management (IPM and IDM), improved integrated nutrient management (IINM), water-saving technologies, precession farming, waste land management, increasing irrigation facility, improved weather based agro-advisory, creation of seed bank, crop insurance, agro-horticulture, agro-forestry, use of non-conventional energy and indigenous technical knowledge for adapting to climate change.

The introduction of climate resilient varieties and contingent crop planning with major emphasis on horticultural crops are two viable technology options for climate resilient agriculture. Horticultural crops not only provide nutritional security but also ensure economic prosperity. Precision farming, protected cultivation and organic production of high value horticultural crops can increase farm profitability many-fold under a changing climate.

Effective climate smart technologies like crop diversification, conservation agriculture, bio-organic management, nitrogenous fertilizer management, intensification of crop production, rain water harvesting, multiple use of water and soil and water conservation measures have been developed for Manipur and these technologies need to be demonstrated on a larger scale. Timely availability of quality seed/planting material of recommended climate-ready crop varieties and irrigation water are two most important requirements for CRA in hills.

The IFS and integrated watershed development (IWSD) should be the focal point for any climate change action, especially in hills. IFS is considered to be a climate resilient production system. It can pave the way for a quantum jump in productivity on a sustainable manner and also ensure better livelihood security to the resource-poor people in fragile ecosystems[16]. Diversified agriculture, IFS and integrated livestock development for food security, markets and economic resilience have been suggested by some researchers[34]. Adoption of low external inputs farming, local weather based agro-advisory, contingent crop planning and water budgeting as well as energy efficiency, agripreneur development and capacity building as cross-cutting components for CRA have also been emphasized[35]. Such approaches need to be undertaken in large areas with community involvement. Special emphasis need to be given to 'jhum improvement module' (JIM).

For plant health management, available IPM and IDM modules should be disseminated among farmers highlighting eco-friendly insect-pests and disease management. However, plant health management should also focus on developing loss assessment and disease forecasting systems using the available information on climatic variables and disease/pests.

For livestock sector, climate resilient breeds should be popularized with special emphasis on climate smart breeding strategies, production adjustment, herd management, grazing management, housing and feed management. Improved feeding practices with supplements and additives as well as improved disease management are ways to reduce methane emissions from enteric fermentation. Emphasis should be given to on-farm manuring to minimize the emission of GHGs and to increase the availability of organic source of nutrients for the crop husbandry. The locally available indigenous genetic resources of livestock and poultry are major gene pools for adaptability, resilience and resistance to the various kinds of stresses. Hence, characterization, conservation and utilization of these genetic resources need to be emphasized in view of climate resilience[36].

Disease surveillance, monitoring and early warning system are important steps for detection of trans-boundary and emerging diseases in livestock. To ensure year-round fodder availability, locally available feed and fodder resources need to be identified. Establishment of 'community fodder farm' (CFF) could meet the fodder and minimize the free grazing problem during winters.

In fishery, high value climate resilient fish species should be introduced. Protection and conservation measures for potential fish stocks in selected cold water areas (upper stretches of hill streams/lakes) are indispensable. Establishment of cold water fish hatchery especially for indigenous fish species, establishment of 'fish seed bank' for safeguarding aquatic resources, popularization of cold water fish farming techniques like pond culture or cage culture, species diversification and bringing more area which is unsuitable for crop production under fish farming are different options for cold water fisheries. Displacement of cold-water species occurs in many areas with changing climate. Hence, studies on hydrobiology of different stretches of hill streams and lakes of upland need to be undertaken in addition to physiological changes and emerging diseases of fish in relation to climate change.

Market-driven secondary agricultural activities are of prime importance for sustaining the livelihood of the farming community through additional income generation. Various options for secondary agricultural activities include mushroom production, bee-keeping and honey production, primary processing of horticultural crops, enriched vermicomposting, etc. All these activities should be cluster-based and integrated with suitable packaging facility and marketing network. Sericulture can be linked with agro-forestry. However, such activities should be demand-driven, location-specific and of a participatory manner, with special focus on gender specific needs and social priorities of indigenous communities. There is an urgent need for women friendly farm tools and implements.

Sustainable intensification of climate change action in Manipur requires introduction of climate ready varieties/species/breeds, IINM or organic nutrient management (ONM), increase in water availability especially during lean period and IFS-based approach with special emphasis on carbon sequestration and waste management. Technology transfer and capacity building of farmers, especially the small land holders should be the crux of any climate change action. Emphasis should be given to climate resilient production system and climate resilient eco-system for 'ecosystem based adaptation (EBA)'. However, the interactions between adaptation strategies must be considered, along with mitigation potential of the adapted system[37]. Climate awareness programme, front line demonstrations and farmer field schools would be helpful for farming communities to tackle climate change associated challenges. Organic farming is considered as one of the available options for combating challenges of climate change as it uses eco-friendly approaches, promotes carbon sequestration and improves soil and environmental quality. Manipur has enormous scope for production and export of organic products. Farmers, especially in hills, have a strong mindset against the use of chemicals and hence, Manipur is often termed as 'organic by default'. The state contributes only 3% of the certified organic area in north eastern region of India as compared to Sikkim (57%), Nagaland (17%), Mizoram (16%). Approximately 1296.91 hectares of the state is under organic production including wild harvest[38]. Pineapple, turmeric, ginger and chillies are the major organic products and organic production packages of these crops have already been developed by ICAR.

Policy options for climate resilient agriculture

Climate change has the potential to fatally derail the food production scenario of the country. Assessing village level vulnerabilities for climate variations is important to build resilience of the local people and their livelihoods. Therefore, multidisciplinary collaborative approaches need to be devised for achieving durable climate resilience in agriculture. Targeted and dedicated efforts from various departments, developmental agencies and government policies will help achieve sustenance in agriculture. In addition, 'public–private–civil society partnership (PPCP)' approach should be promoted.

Consequently, there is a growing clamour for adopting programmes and policies for sustainable agriculture with focus on conservation agriculture, CSA, organic farming etc. Eliminating existing detrimental policies that can exacerbate climate change impacts is of utmost importance. 'Climate proof planning (CPP)' integrated with disaster preparedness or risk reduction is required for mainstreaming climate change and adaptation. For 'climate compatible development (CCD)'[39], more financial support should be provided.

Year round availability of water can play a great role in increasing resilience of mountain agriculture against changing climate. In addition, 'water and energy efficient integrated participatory watershed development programme' has to be at the core of improved agriculture, to ensure conservation of valuable natural resources without compromising on productivity. Special government policy/programme is needed for creation of water resources. Policy should also be formulated for 'water and energy budgeting in agriculture'.

In hilly terrains, weather varies with altitude, location of the hills, etc. and establishment of weather station at one location cannot represent the weather of entire district/zone. Preparedness to weather extremes is most important. Hence, equipping farmers with capacities and capabilities to combat climate change through local automated weather stations will help in generating location-specific crop advisories more effectively. This as a whole will help implement location-specific crop contingency plans and to minimize losses. Dedicated 'national programme on climate information and early warning systems' would help in decision-making by the small and marginal farmers.

The conservation and utilization of indigenous crop varieties need to be promoted, while making a balance with the use of high yielding and hybrid varieties. 'National seed programme on climate resilient and indigenous varieties/breeds of crops and livestock' needs to be undertaken. However, research to assess the climate-resilient characteristics of indigenous varieties is necessary under NICRA. Besides, dedicated funding is required for development of 'contingent seed bank' in each and every state.

Instead of crop-based programme, policy should be formulated for launching 'system based programme' and the value of sustainable farming should be increased through carbon valuation. Government policy should include promoting 'system of crop intensification' (SCI) as it is resistant to climate variability. This low-input system enhances productivity with higher input use efficiency and also maintains the resource base. Similarly, for minimizing the use of chemical fertilizers, mission mode schemes on organic farming need to be integrated with climate change action programme.

Reduction of agricultural waste is highly essential. Improvement of storage possibilities, and its decentralization along with value addition of perishable goods are vital to reduce carbon footprint simultaneously. Income generating secondary agricultural activities like community-based value addition programme, integrated beekeeping and honey processing unit, value added or enriched vermicomposting, integrated mushroom production and processing unit etc. should be popularized.

Insurance products should contribute to climate change adaptation and risk reduction must be rewarded upfront. Hence, instead of yield-based index for crop insurance programme, 'weather index based crop insurance' should be introduced[40].

In case of livestock sector, 'rural livestock health mission' should be launched. 'Disease referral, surveillance and monitoring laboratory' should be established in each and every state. Emergence of new diseases or transboundary diseases is gaining importance with changing climate. Hence, establishment or strengthening of quarantine stations is required at check gates in border areas.

Adaptation is considered a local phenomenon. Hence, there is an urgent need for seamless blending of traditional wisdom and modern scientific technologies to devise locally suitable adaptive strategies for agriculture. Transfer of knowledge and information actions (improved Agro-advisory Instrument focusing Climate Related Issues) should be given high priority during policy formulation. Government should also adopt a policy for inclusion of core course on 'climate change' in agricultural universities.

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