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ADAPTATION AND MITIGATION OF CLIMATE CHANGE THROUGH AGROFORESTRY IN INDIA

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Abstract: Global warming and climate change, both are already making our planet less inhabitable, with all extreme events like droughts, floods, cyclone and other weather events. Stabilizing the climate is perhaps the central challenge for humanity in the early decades of this century. Globally, a massive switch has been made to evergreen agriculture practices including agroforestry by recruiting perennial crops and trees into cropping system, ensure climate resilience and to sequester more carbon and reduce emissions. By providing farmers with a means of producing fuel wood, timber, building poles and other forest products on farmland, agroforestry can significantly reduce the demand on forests and natural woodlands. By doing this in ways that enhance and sustain agricultural productivity, agroforestry can also alleviate some of the pressure from climate change by delivering both mitigation and adaptation and makes the land use system sustainable.

Keywords: Climate change, mitigation, adaptation, agroforestry

1. INTRODUCTION

Global warming and climate change are important environmental issues affecting human lives and systems of planet earth and has captured the world's attention during the recent past. Much of the increase in global average temperature since the mid-20th century is due to the increase in concentration of greenhouse gases (GHGs). Carbon dioxide (CO2) is the most important anthropogenic GHG whose concentration increased globally due to fossil fuel use, aggressive increase in industries and developmental needs and land-use change etc (Patil et al. 2012). The recently released *fifth Assessment Report* from the intergovernmental panel on climate change (IPCC) presents a range of scenarios that forecast between a 1°C and 5°C temperature rise above preindustrial levels by 2100. Climate models also predict that heat waves will become more frequent and extend over longer periods (Wreford et.al 2010). Rainfall patterns are expected to be extensive destruction of agricultural lands, property and human life including health. This will be one of the great challenges of the 21st century, as the IPCC is unequivocal in stating that the poorest will be hit the hardest. The climate debate often overlooks how adaptation can result in economic and financial opportunities for smallholder farmers. Taking into account long-term climatic production and spread climate risk across different income streams, or sustainably intensify to maintain stable harvests in a more resilient natural environment to address all issues relating to quality life and tenural security (Hitz and Smith 2004 & Singh 2014).

However, climate change is a real happening now and all the systems are affected by it. It is not that the climate has started changing

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only now, it has been continuously changing in the past, and is expected to continue doing so in the future also. However, the impact of climate change is increasingly being noticed on account of the likelihood of its occurrence and the severity of extreme events, may they be the droughts, floods, heat waves, cloud bursts, sea level rise and so on so forth. Now, climate change and food insecurity are two most pressing challenges human beings are facing today and has emerged as the biggest twin challenge of this century. There are evidences that the increase in greenhouse gases caused by human activities is responsible for global warming and consequent climate change (FAO, 2007). Under the six emissions scenarios the global average surface temperatures are expected to increase by 1.1°C - 6.4°C this century [IPCC, 2007]. Climate change has its impact on almost everything on the earth and so on the food production. The agriculture plays a very important role in the economy of most of the nations of the developing world. For India, agriculture is the base of nation's economy, largely rainfed and dominated by smallholders (Singh 2008 and 2010). As per reports from a number of governments, non-government and intergovernmental organizations, the countries and agriculture especially practiced by smallholders are particularly vulnerable to climatic changes and they have least capacity to adapt to these changes. In most of the developing countries of the world, the agriculture is not merely a matter of cultural practice but it is the source of livelihoods of millions of smallholders and their dependents. Changing climate as predicted will not only affect the agricultural productivity but also heavily hit the lives and livelihoods of the smallholder families and ultimately lead to food insecurity to the concerned nation and the world (Singh et al. 2012). Business-as-usual scenarios of population growth and food consumption patterns indicate that agricultural production will need to increase by 70 percent by 2050 to meet global demand for food. South-Asian countries made tremendous progress in food production in 1960s, 1970s and 1980s with an impressive growth of food production, India, Pakistan, Bangladesh and Nepal transformed themselves from countries with a chronic food deficit to countries that were almost self sufficient in early 1990s. Except Afghanistan, all these countries had exported some quantities of food grain in late 1990s. The dynamic growth in the agriculture sector has, however, recently been lost. Productivity of major food grains has slowed and has been decline for some crops (Kumar et al. 2008) with food production failing to keep pace with population growth (Rasul and Schild 2009). As a result, South- Asian countries are now finding it difficult to meet their population most basic food and nutritional needs and remain vulnerable to food insecurity. A large segment of climate change has been attributed to the uncontrollable natural causes, and anthropogenic factors, the irrational & unjustifiable human activities. Whatever the causes, everybody throughout the globe has experienced suffering from the ill effects of climate change (Sahoo & Singh 2015).

In the changing climate, there are three ways to live: one is to simply tolerate the conditions and continue suffering, second one is to continually develop adaptation techniques for living comfortably, and the third one is to stop the climate from changing by stopping the actions that cause climate change. There are a series of debates and Global Conventions, Conference of Parties, including Kyoto, Bali, Copenhagen, Cancun, Doha, Warsaw and Peru that go in cycles about mitigating climate change through fixing of responsibilities, developing global mechanism for shouldering of the costs of restoring the environment, devising of the reward and punishment systems, etc., but without any tangible all party acceptable frame work, or agenda.

2. CLIMATE CHANGE EFFECTS IN INDIA

The agriculture sector is not only among the most vulnerable sectors to the impacts of climate change; it is also directly responsible for the 14 percent of global greenhouse gas emissions. In addition, the sector is a key driver of deforestation and land degradation, which account for an additional 17 percent of emissions [FAO, 2009, 2010]. The agricultural sector can be an important part of the solution to climate change by capturing synergies that exist

among activities to develop more productive food systems and improve natural resource management (Sahoo et al. 2014b). Sustainable utilization of natural resources will require management and governance practices based on ecosystem approaches that involve multi-stakeholder and multi-sectored coordination and cooperation. This is a crucial element for the transformation to climate resilient agriculture. More productive and resilient agriculture is built on the sound management of natural resources, including land, water, soil and biodiversity (Nanda and Garanayak 2010). Conservation agriculture, agroforestry, improved livestock and water management, integrated pest management and ecosystem approaches to fisheries and aquaculture can all make important contributions in this area. According to IPCC 4th assessment report, agriculture is currently responsible for about one third of the World's GHG emissions and this share is projected to grow, especially in developing countries. To support food security and boost incomes, agricultural systems in developing countries will be under pressure to increase productivity sustainably and strengthen the resilience of agricultural landscapes. Strategies exist to sequester carbon and reduce greenhouse gas emission reductions in the agricultural sector. Many of these strategies also improve food security, foster rural development and help communities adapt to climate change. However, tradeoffs may have to be made when seeking to reach different development goals, such as climate change mitigation and adaptation, sustainable agricultural production and poverty reduction.

The main effects of climate change in India could be seen in the vulnerability dimensions of the country, as has been recently articulated by the Ministry of Environment, Forests and Climate Change. The emerging patterns of monsoon, eventually expected rise in the mean sea level, water scarcity due to melting of glaciers and the confluence of mineral wealth with the forested resources are some of the issues to be worried about at the national level. There are two main and noticeable trends in climate change. The first one is a rise and swing in temperatures, reflecting in shorter and warmer post- monsoon and winter seasons, and prolonged summers with higher temperatures and intense heat waves. The second one is the shifts in the on-set and secession of rainfall and shorter rainy season, resulting in prolonged droughts, and high intensity rainfall concentrated over a shorter period resulting in higher velocity flows and deeper depth floods. The resultant hydrological situation however, in most cases is not only determined by the amount and intensity of rainfall. It is a combined reflection of the precipitation and physiographic parameters in the general landscape. For example, a low lying land could experience submergence even at a smaller amount of rainfall, whereas a slopping land may have droughts with twice the amount of that rain. Though there is no appreciable rise in the sea level and in the extent of coastal flooding yet, a noticeable increase in the salinity levels of the inland and backwaters has been recorded at several places in the country. About 250 million population of the country, residing within 50 km distance from the coastline will be highly vulnerable if the salinity or the sea level rise phenomena continues in future. Similarly, though the rate of retreating of Gangotri glacier is slowing a bit, most of the other glaciers feeding Indian- river system in general have been recorded to be retreating. Only the Siachen glacier is noted to be advancing. These elements are resulting in the decline of river flows which limit potentials for irrigation and domestic uses, a decrease or total loss of crop productivity, loss of livelihood opportunities and a greater risk on investment in agriculture. At other times they cause the same magnitude of damage albeit via floods. Both these increase social expenditure. The exploitation of the mineral wealth has a direct relationship with the loss of the forested area, biodiversity, ecological services and other forest wealth. The adverse effects of climate change indeed are many fold and irreparable in many instances, as they affect the resource flow and also impact the availability of resources for use directly, or indirectly.

As has been mentioned earlier, the two most often recorded effects of climate change are the delays in the onset and decrease in the amount

of effective rainfall, resulting into droughts, and the high intensity rainfall resulting in the floods. Both these events contribute equally and negatively to agricultural productivity and food and livelihoods security, as has been witnessed in 2009 and 2010. However, it must be recognized that there is a wide variation in the characteristics of both these events. They are not uniform and as a consequence have differential impact as well as mitigation strategy. For example, take the case of drought. Drought has its categories, each one of which has its own impact. To begin with, any delay in rain from the expected date of onset is essentially a climatic drought and its effects are on the wage earners, landless, domestic water supply, etc. Normally even a week's delay becomes a big issue because of the expectations of transition from intense summer to the rainy season, although it is of no practical consequence to agriculture. No major change in crop growing practices or in systems are warranted in such a situation. Similarly, a drought past the date of any significant delay in field operations, e.g. land preparation, sowing etc., is an agricultural drought and is of agricultural consequences. Some adjustments in the farming practices may be necessary to overcome this consequence. And, when the drought starts affecting the crop yields, or occurring at a time when there is no chance of recovery from it and also there is no other option for alternative livelihoods, it is an economic drought and has to be dealt with expeditiously. If drought continues further and takes the shape of a famine, it is a social calamity and has to be addressed in another manner. The flood situation is of similar nature and has to be dealt accordingly.

A number of sources of the greenhouse gases (GHGs) have been identified to be contributing to the climate change and carbon has been singled out to be the largest contributor among them. There are numerous sources of such a carbon, fossil fuel and biomass burning, inappropriate agricultural, domestic / municipal and ecosystem management practices, etc. Methane, nitrous oxide, chlorofluorocarbon, halocarbons and troposphere ozone are among the other and more dangerous sources of global warming. The emission of greenhouse gases will continue, resulting from various developmental initiatives. While every effort should be made to mitigate climate change effects, it is very important to build up adaptive capacity and reduce the vulnerability of the natural resources and the communities. Strategies for adaptation should focus on the people most affected by climate change and aim to reduce the most significant hazards they may have to face.

3. AGRICULTURAL LAND-USE IN INDIA

Indian agriculture has various features to its credit. It involves a number of commodities or crops and enterprises. It is sectorial as well as inter-sectorial, is practiced on private and public lands, and has a number of social dimensions and implications. Agriculture in India is being practiced in a variety of climatic conditions, ranging from sub temperate to highly tropical and from arid to humid conditions. Despite of numerous irrigation sources, a majority of it is directly rainfed, because in a large chunk of the country irrigation facilities do not simply exist, and in other places where they do, water supply is not adequate due to a variety of reasons, such as the erratic and insufficient supply of fuel, electricity and insufficient storage of the rain water in the reservoirs. At the most they can be classified into partially irrigated category.

Due to intensive agriculture several ills have also appeared in Indian agriculture, such as declining factor productivity, degradation of natural resource base, environmental degradation including ground water depletion & contamination and declining farm profitability & productivity (Gill *et al*., 2009). To tackle such problems, agroforestry systems approaches to research has been widely recognized, where whole farm is viewed as a system and interactions among the various components are taken into consideration (Nanda et.al.2007). Efficient integration of crops with animals (cow, buffalo, pig, goat, sheep, fish), birds (poultry, pigeon, duck), multipurpose trees and other enterprises (bio-gas, apiary, mushroom, etc.) clearly showed the best advantages over conventional system of cropping under irrigated and rainfed conditions as well as in tribal areas (Jayanthi *et al*., 2001). Integrated Farming System (IFS) including

agroforestry focused around a few selected inter-dependant, inter-related and often inter-linking production systems seems to be the viable alternative to ensure food, nutritional and economic-security, particularly to the large chunk of small and marginal farmers of the state (84%), which operate under complex-diverse-risk prone environment. Adoption of such system provides high opportunities of productivity enhancement, employment, income generation, nutritional security and a climate resilient agricultural production system by diversifying and integrating different components of farming viz., crop, horticulture, livestock and fisheries. The systems based on multiple recycling of carbon, energy and nutrients would also help minimize environmental loading with pollutants. Mixed farming involving tree- crop or crop-livestock integrations has become a way of life and means to livelihood in rural areas of the state, where crop/ tree/ livestock and livelihoods are intimately related. About 85% of livestock in the state are owned by the landless, marginal and small farmers and 80% of rural households depend on livestock from where they draw 30% of their annual income for sustenance. About 70% of total poultry are of local backyard breeds, which were again owned by the down trodden ones. The livestock component acts as a stabilizing factor in the system, thus needs strengthening of the crop and livestock linkage to enhance the economic viability and sustainability of the farming systems. Further, Livestock and livelihoods are intimately related and the ownership of livestock is more egalitarian than that of land (Swaminathan, 2010).

4. CLIMATE CHANGE RISKS IN INDIA

There are a number of risks associated with the climate change, each of which needs a separate risk aversion strategy. Most of these risks are related to losing the wages & employment, total crop or its partial productivity, investment, assets and livelihoods, and their combination in a variety of ways. From agricultural point of view, crop productivity data alone provide sufficient insights into the kind of risks farmers are faced with as all other types of risks are strongly related to this. Since the crop productivity is principally a reflection of technology application under certain environmental conditions, it is essential to determine how much of the productivity is contributed by the technology and how much by the environment. Assuming that the risks are due to climate change, they can be managed in categories of mitigation, adaptation, and avoidance / minimizing / spread of risks. They each have different options and implications. It will be prudent here to mention that climate change cannot be mitigated; no one can stop the climate from changing itself, only the effects of climate change can be mitigated. And the mitigation of the effects is essentially an adaptation mechanism. Therefore, there is a very thin line between the mitigation of climate change effects and adaptation to climate changes (Singh 2014).

5. MITIGATION OF CLIMATE CHANGE

This strategy is a snap shot dealing of the problem, mainly to lessen its impact through monitory means. This is somewhat compensatory in nature and involves dole outs, such as the free food, writing off the loans, providing concessions and subsidies, etc. for compensating the losses to some extent. It is neither for problem bypassing, solving nor avoiding, and there are no changes suggested in the system or the practices (Garrity et al. 2010, Huxley 1996) This is the strategy that has been noticed to be often adopted across the globe during any calamity, be it a climatic, accidental, or something else (Nair et al 2009). Governments and international rush to announce relief packages of so much worth immediately at the outset of the problem, but often without any programs to deal with such problems by way of bypassing, solving or avoiding them in the future.

6. CLIMATE CHANGE ADAPTATION

This approach is to develop ways and means for adapting to the prevailing conditions thereby, to insulate the system from the negative impact of the problem. It is somewhat problem bypassing in nature. This strategy requires making changes in practices and sometimes also in systems so that they can withstand and adjust well to the prevailing conditions. The approach builds

protocols and community capacity to deal with the problem as and when needed and provides the community with a variety of options (practices and systems) to choose from. It is knowledge intensive and needs the participation of public, private and community institutions. The strategy puts a heavy focus on training and skills enhancement on new techniques and methods, and demands public fund investment on building such institutions. This is one area where revisit and assessment of the available technologies and their re-synthesis needs to be packaged and validated in actual (on-farm) prevailing climatic conditions. Once validated, they can be disseminated to the communities for their adoption and applications (Sanchez 1995, Torquebiau 1992 & Torquebiau 2000).

7. AGROFORESTRY: A SUCCESSFUL TOOL TO COMBAT CLIMATE CHANGE

In many parts of the world, agro forestry approaches and practices can be particularly relevant for addressing the nexus of efforts to (1) eradicate poverty and hunger and (2) ensure environmental sustainability. In addition, agro forestry may also be able to improve resilience of livelihood systems to shocks associated with periodic crop failures due to impacts of climatic or market fluctuations on particular production components. It may also provide a more resilient platform for adaptation to future climate change. Agro forestry is uniquely placed in terms of related mitigation options as it can be designed and implemented to be compatible with adaptation strategies, and can have substantial co-benefits in terms of biodiversity, watershed conservation, employment, food security and income generation. It is a way of farming trees with the field crops outside the forests in a variety of designs, configurations and combinations to optimize the use of natural resources, leading to the sustainability of the system. Herein, the choice of tree and the field crop combination varies by the local preference, market demand and experience and the resources of the producers to invest on it (UNFCCC 2008, Verchot, et al 2007).

However, agroforestry system is an old practice, but relatively a new science. As a practice, it has been recorded for over centuries, but as a science it has received attention only some 40 years ago, or so. Agroforestry systems enhance livelihoods, and contribute to resolving major development and global environmental problems, including the climate change effects. In general, agroforestry systems are ecology specific, and natural resource domain bound. These systems allow effective integration of crops, woody perennials, livestock, and pastures in a synergistic manner and can be practiced on a range of land form situations, climatic conditions, social settings, and regulatory mechanisms, such as the land tenures, etc.

Agroforestry is a traditional system in India and is recognized as an optimal multifunctional land use system that provides a variety of important benefits. It has numerous forms and combinations, ranging from timber based systems in the north- western part of the country to the Kerala home gardens, Khejri based systems in the semi-arid/ arid regions of Rajasthan, and mango and tamarind based fruit systems in Tamil Nadu, Karnataka and Andhra Pradesh, and so on. It is known to reduce pressure on forests through increasing on –farm production, lowering of fallow rotation in shifting cultivation, bringing wastelands under economic use and avoiding environmental health hazards. Currently, these systems in India are recorded to meet 65% of the country's timber demand. The timber production statistics shows the on-farm productivity to be in the range of 18-20 cubic meter / ha per year as against from the best managed forests of 2-3 cubic meters / ha per year.

In the context of climate change, agroforestry systems are also known to sequester significant amounts of carbon, both in the below ground and above ground biomass. In the below ground biomass, they sequester carbon amounts similar to the primary forests and managed forests. In the above ground biomass, the sequestered carbon amounts far greater than by the annual crops, pastures and grasslands. Depending upon the rotation cycle or harvesting cycle, these systems are capable of easily sequestering anywhere between 5-100 t of carbon per ha. In here, the long rotation systems have large potential in above ground biomass, and the short rotation systems for the soil carbon sequestration. Also the fast

growing hardwoods have larger potential for above ground biomass than the slow growing species in the same period of rotation cycle. However, both these types have similar soil carbon sequestration potential in any given rotation cycle. Therefore, the agroforestry systems, which normally integrate short rotation species, are of particular significance because of their desirability by the producers for income in a shorter period of time and the grater possibilities for carbon to remain sequestered longer because it is held below the ground. In summary, agroforestry systems provide the climate change mitigation mechanisms through increased CO2 assimilation, stabilized yields providing biological and economic gains, improvement in the production environment through the enrichment of natural resources, further enhancing CO2 assimilation and carbon sequestration (Lasco and Pulhin 2009). So, these systems are water positive and carbon positive, ensure good tenure, food security and redress issues relating to climate change, both mitigation and adaptation (Singh & Sahoo 2011, Sahoo 2012, Sahoo 2014a and Zomer, et al. 2009).

8. CONCLUSION

Needless to say, agroforestry systems offer a range of benefits and in quantities incomparable to any other agricultural systems. Their specific niches however, are to be mapped and their recommendation domains delineated. Recommending validated and specific agroforestry models according to the landholding size and farming systems in different ecological conditions are expected to accelerate the adoption of these systems, and thereby significantly contribute to the livelihoods and environmental security of the people in the vulnerable and fragile settings, such as the rain-fed, dry and tribal population inhabited areas in the country. The way forward is to treat agroforestry systems as a specialized way of farming, in which the integration of tree crops is done with the field crops, annuals, perennials, high value commodities, etc. and the integration is guided by the "high value low volume" principles. The next area is to encourage and promote growing of trees in agricultural landscapes and homesteads with adequate technical backup on tree type, tree density and tree and plantation management, along with the provisions for the supply of high quality planting material. This should be supplemented by afforestation of the marginal and degraded lands.

In order to have a large scale impact in the country, agroforestry efforts at the national level therefore, should strategically focus on tackling poverty, food security and environment through four channels: a) overcoming natural resource degradation in intensive irrigated systems, b) arresting land degradation in smallholder farms in sub humid and semi- arid areas, c) searching for alternatives to slash and burn in tropical humid areas, and d) providing shelter belts in the coastal areas.

Now, agroforestry has increasingly become a focal entry point for livelihood development and for environmental stewardship, notably as climate change adaptation and mitigation has risen in importance. In order for agro-forestry to increase its contribution to meeting evolving needs of farmers and society within this changing operational and policy environment, it needs to improve its ability to evolve within and to influence this changing policy context. It is the time to promote agroforestry systems through Climate Smart Agriculture practices for a food secure world through the provision of science-based efforts that support sustainable agriculture and enhanced livelihoods while adapting to climate change and conserving natural resources and environmental services with focus on developing countries. Further, it will be a part of the solution by contributing to climate change mitigation, through carbon conservation, sequestration and substitution, and establishing ecologically designed agricultural systems that can provide a buffer against extreme events. So, agroforestry is important both for climate change mitigation as well as adaptation through reducing vulnerability, diversifying income sources, improving livelihoods and building capacity of smallholders to adapt to climate change. Further, strong local institutions are in need for identifying, coordinating and recognizing informal rights and strengthening customary systems while scaling up agroforestry practices in the country.

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