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Chapter 13

Farming System Approach to Reduce Impacts of Climatic Change

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1. Introduction

Plantation crops mainly coconut, rubber, tea, coffee, oil palm, arecanut, cashew, cocoa are grown in ecologically sensitive areas such as coastal belts, hilly areas and areas with high rainfall and high humidity. Amongst these, coconut is the major crop in India grown in almost 2 m ha while others are grown in 0.5 m ha or less areas. To meet the projected demand of 22 billion nuts in 2025 from the present supply of around 15 billion nuts, need adaptation measures that are most likely to be effective in improving yields of coconut grown under drought, flood and high temperature conditions in future climates. Coconut is grown between 20° N and 20° S latitude. It can be grown even at 26° N latitude but the temperature is the main limitation. The optimum weather conditions for good growth and nut yield in coconut are well distributed annual rainfall between 130 and 230 cm, mean annual temperature of 27 °C, abundant sunlight ranging from 250 to 350 Wm^{-2} with at least 120 hours per month of sun shine period. Since, it is humid tropical crop it grows well above 60 per cent humidity (Child 1974, Murray 1977). The generally recommended levels of major nutrients like NPK is at 500 g N: 320 g P_2O_5: 1200 g K_2O per palm/year. The recommended irrigation levels are 200L/palm once in 4 days or @ 66 per cent Eo through drip irrigation (Rajgopal *et al.*, 1999). Any deviations from these optimal conditions cause the palms to experience the stress conditions.

Climate change will affect coconut plantation through higher temperatures, elevated CO_2 concentration, precipitation changes, increased weeds, pests, and disease pressure, and increased vulnerability of organic carbon pools. In order to predict the future coconut production a coconut simulation model Infocrop-COCONUT (CocoSim) was developed (Naresh Kumar *et al.*, 2008). Simulation analysis using the model indicates that under all storylines, coconut productivity is projected to go up by up to 10 per cent during 2020, up to 16 per cent in 2050 and up to 36 per cent in 2080 over current yields only due to climate change. However, in east coast yield is projected to decline by about 2 per cent in 2020, 8 per cent in 2050 and 31 per cent in 2080 scenario over current yields due to climate change. Yields are projected to go up in Kerala, Tamil Nadu, Karnataka, Maharastra while they are projected to decline in Andhra Pradesh, Odisha and Gujarat (Naresh Kumar and Aggarwal, 2009; 2013). Coconut has adaptive strategies to withstand or overcome the stress conditions at morphological, physiological, biochemical, anatomical and molecular levels (Kasturi bai *et al.*, 1997). In this chapter the response and adaptive strategies of coconut are discussed with respect to climatic factors like high CO_2 effect and the consequences of climate change like drought and high temperature.

2. Climate Change Impact

In open top chamber (OTC) experiments it was observed that coconut seedling growth was promoted with [ECO_2] while, elevated temperature [ET] 3°C above ambient reduced the growth (Naresh Kumar, 2007; Hebbar *et al.*, 2013b). 700 ppm [ECO_2] increased plant height, leaf area and biomass production of coconut seedlings by 18 per cent, 16 per cent and 15 per cent respectively, as compared to ambient 380 ppm. The higher root biomass accumulation indicated better CO_2 sequestration with [ECO_2]. Higher growth was due to both increased leaf area and photosynthesis. On the other hand, ET significantly reduced both photosynthesis and leaf area and thus the plant growth. In open top chamber (OTC) experiments it was further observed that the stimulatory effect of CO_2 under drought was less and it could increase the biomass by only 8 per cent at 700 ppm CO_2 (Hebbar *et al.*, 2013a). However, both under normal and water limited condition there was reduced stomatal conductance and transpiration with elevated CO_2. Thus, the water requirement to produce unit biomass in ECO_2 treatment is less. This indicated that, at the present level of moisture available coconut would produce more biomass under future climate. However, with the projected reduction in precipitation under future climate the biomass production and nut production may be reduced unless corrective measures are taken. Similar to the above ground biomass below ground biomass i.e, root biomass too increased with elevated CO_2. Thus, it is expected that there will be higher carbon sequestration under future climate which is an important option to mitigate the climate change effect.

2.1. Moisture Deficiency

More than 60 per cent of coconut cultivation is rainfed and over 50 to 60 per cent yield loss is due to drought stress. Extensive work has been carried out at CPCRI to characterize the drought prone areas, to assess the impact and identify the critical stages. Coconut drought is characterized in different agro-climatic zones *viz.*, Western ghats high rainfall zone (Kidu-Karnataka), Western coastal area - hot sub-humid-per-humid (Kasaragod - Kerala; Ratnagiri - Maharastra), hot semi arid

(Arisikere - Karnataka) and Eastern coastal plains- hot sub-humid (Veppankulum-Tamil Nadu; Ambajipeta- Andhra Pradesh). Weather data based characterization of drought and its intensity indicated variations in length and number of dry spells in each zone (Naresh Kumar *et al.*, 2007). Apart from this they also differed for rainfall, temperature regimes and light intensities, thus bringing about the different intensities of drought.

2.2 Response to Elevated CO_2 and High Temperature

In open top chamber (OTC) experiments it was observed that coconut seedling growth and biomass increased at elevated CO_2. At 550 and 700 ppm CO_2 the biomass increased by 8 and 25% respectively against ambient CO_2 concentration of 380 ppm (Hebbar *et al.*, 2013). High temperature on the other hand significantly reduced the biomass (Table 13.1). Elevated CO_2 to certain extent could offset the negative effect of temperature in coconut. Drought also significantly reduced the biomass production across all the treatments. The stimulatory effect of CO_2 under drought was less and it could increase the biomass by only 8% at 700 ppm CO_2. CO2 was closely associated with the photosynthesis (PN).

Table 13.1: Biomass Production of Coconut Seedling in OTC with Climate Change Variables ECO_2, ET and Drought

Climate variable *Volume (cm^3)* *Root length (cm)*	*Root wt (kg)*	*Stem wt (kg)*	*Leaf wt (kg)*	*Biomass (kg)*
Ambient 94 752	0.218	0.406	0.398	1.022
550 ppm CO2 98 875	0.247	0.446	0.433	1.126
700 ppm CO2 105 992	0.269	0.487	0.460	1.216
ET 110 638	0.195	0.346	0.370	0.911
ET+550 ppm CO2 116 736 Treatments	0.218	0.380	0.390	0.988
Control 112 852	0.273	0.523	0.461	1.257
Drought 107 581 CD at 5%	0.113	0.234	0.238	0.584
OTC 8 77	0.017	0.022	0.028	0.037
Treat 6.45 59.67	0.014	0.017 0	.022	0.029

Prolonged periods of temperatures above the maximum tolerable limit can hamper vegetative growth as well as reproductive development and consequently the yield. Pollen of crops, since they have to stay viable in the field after anthesis until pollination, are exposed to temperature and humidity fluctuations in the atmosphere for a longer period. Also, the pollen development and anthesis stages have been found to be highly sensitive to temperature changes. In coconut most of the genotypes tolerate temperature up to 30oC (Hebbar and Chaturvedi 2015; 2016). Beyond which pollen germination as well as pollen tube length of genotypes decreases. Genotypes among these groups viz. talls, dwarfs and hybrids too showed wide variability for pollen germination across temperatures. Tall variety WCT had high pollen germination at all the temperatures, followed by FMST. Hybrid MYD X WCT performed better than COD X WCT at high temperature. Amongst dwarfs COD was the best at all temperatures (Helen, 2016). So, studies on the effect of high temperature on pollen and the genotypic variation, if any, in the thermotolerance of pollen are important for identifying the ones that can survive in a warmer future. The results may be useful in future breeding programmes aimed at developing climate-smart varieties.

High temperatures can have both negative and positive impacts on growth and production in coconut. The negative impacts such as added heat stress, especially in areas at low to mid-latitudes already at risk today, but they also may lead to positive impacts in currently cold-limited high-latitude regions. Warming trends are noticed in most parts of the coconut growing areas of Karnataka, Kerala and Tamil Nadu. High temperature increases both photorespiration and the dark respiration and thus the total biomass production go down. Regression analysis indicated increase in T min increased the leaf emergence rate: increase in T max increased inflorescence emergence rate; pistillate flower production has curvilinear relationship with rainfall/month (150mm/month-opt), nut retention has curvilinear relationship with T max (32 oC-opt) and Tmin (20 oC-opt). Frequent but short periods of temperature below 15°C result in abnormalities of fruit such as bicarpelate nuts and lack of pollination under North Indian conditions.

Thus, climate change has far reaching implications for plant growth, production and food security, and approaches are required for adapting to new climates. One of the primary approaches broadly exist for adapting plantation crops to these conditions is devising new cropping systems and methods for managing crops in the field. These approaches include the specific strategies as discussed below.

3. Coconut Based Farming System

Coconut is mostly grown in coastal and hilly areas where the rainfall is very high and the soil is poor in nutrients. The soil is sandy or laterite which has very low water holding capacity. With the impending climate change projections of high temperature and reduced rainfall the coconut productivity in these soils may decline in the future climates. Studies conducted at CPCRI and elsewhere indicated that coconut based farming system approach is the best adaptation strategy to overcome the effect of climate change.

In a coconut based farming system, coconut trees are planted as a base crop and all other crops are intercropped using the vertical and horizontal spaces between coconut trees. Coconut is a tree which has no branches and grows straight vertically upwards providing more and more space under its canopy. Its leaves are such that it allows sun light to the crops grown under it. Because of these peculiar characteristics of this tree the coconut based farming system is quite different from other farming system based on other crops. Coconut based farming system is a combination of multiple cropping systems in vertical and horizontal dimensions.

Between two coconut trees, fruit trees such as lime, lemon, guava, pamegranate, custard apple, cocoa, nutmeg, clove, crop which are planted at 15 -20 ft distance. These are medium sized crops both in height as well as canopy and can easily fit in between two adjacent coconut trees. They can be planted simultaneously or after the coconuts are established. It takes 8 to 10 years for all the coconut trees to start yielding properly. Whereas a number of the above mentioned crops start yielding well from 3 -5 years after planting. However, their fruiting period will last only 15 -20 years. By the time the coconut will be in its peak yield stage and will be about 20 ft high. The intercrops may be replaced by any other crop and another cycle of medium sized intercrops can be established.

The space between the coconut tree and the first intercropping is about 15 -16 ft which is more than sufficient for a number of perennial, biennial and seasonal crops. For example within this space two banana plants can be planted. Between banana plants, shade loving crops such as pineapple, turmeric, ginger, yam, elephant foot, etc. are planted. If bananas are not planted then crops like tapioca for tuber as well as fodder (stem, leaves etc.) and fodder grasses can be planted. If fodder crops are planted between the intercrops herbivorous animal husbandry is included. The same area can be intercropped with vegetables, green crops such as maize, jowar, ragi, bajra, soyabean, peg ion pea, black gram, green gram, etc. Either these grains can be sold or may be fed to animals such as poultry, pigs, goats, sheep, rabbits etc. The dung and other waste from these animals will be brought back into the land as manures.

The advantages of cropping systems in terms of sustainability and ecology are

1) maximization of solar energy capture; 2) optimization of soil moisture use and retention capacities; 3) enhancement of soil fertility build up due to higher biomass generation over time; and 4) minimal soil erosion and nutrient losses largely attributed to effective and efficient crop canopies and root systems (Magat, 2007).

3.1. Soil and Water Conservation

The major problem in heavy rainfall areas is the soil erosion due to the direct impact of rainfall and the separation of soil aggregates. Increased ground cover due to adoption of cropping system can control soil erosion by 70- 90 per cent, compared to bare soil or un-cropped condition. The presence of undergrowth vegetation in coconut plantations minimizes soil and water loss through surface runoff as well as evaporation. Rain water infiltration and storage are the indirect benefits of ground cover. Any change in rainfall pattern due to climate change can thus be mitigated by adopting cropping system. The runoff in cropping system was reduced to 1.45 per cent from 14.85 per cent in coconut monocrop. Similarly the soil loss was reduced to 0.9 t/ha in cropping system from 3.12 t/ha in monocropping (Dhanapal *et al.*, 2002).

Nair and Balakrishna (1977) reported more equitable microclimate in side coconut + cocoa cropping system compared to monocropped stand. The crop mixes recorded lower mean maximum temperature, higher relative humidity and reduced evaporative demand. In another study, the soil temperature at 30 and 60 cm depths was 3 to 6°C lower and the variation in the mean monthly soil temperature was the

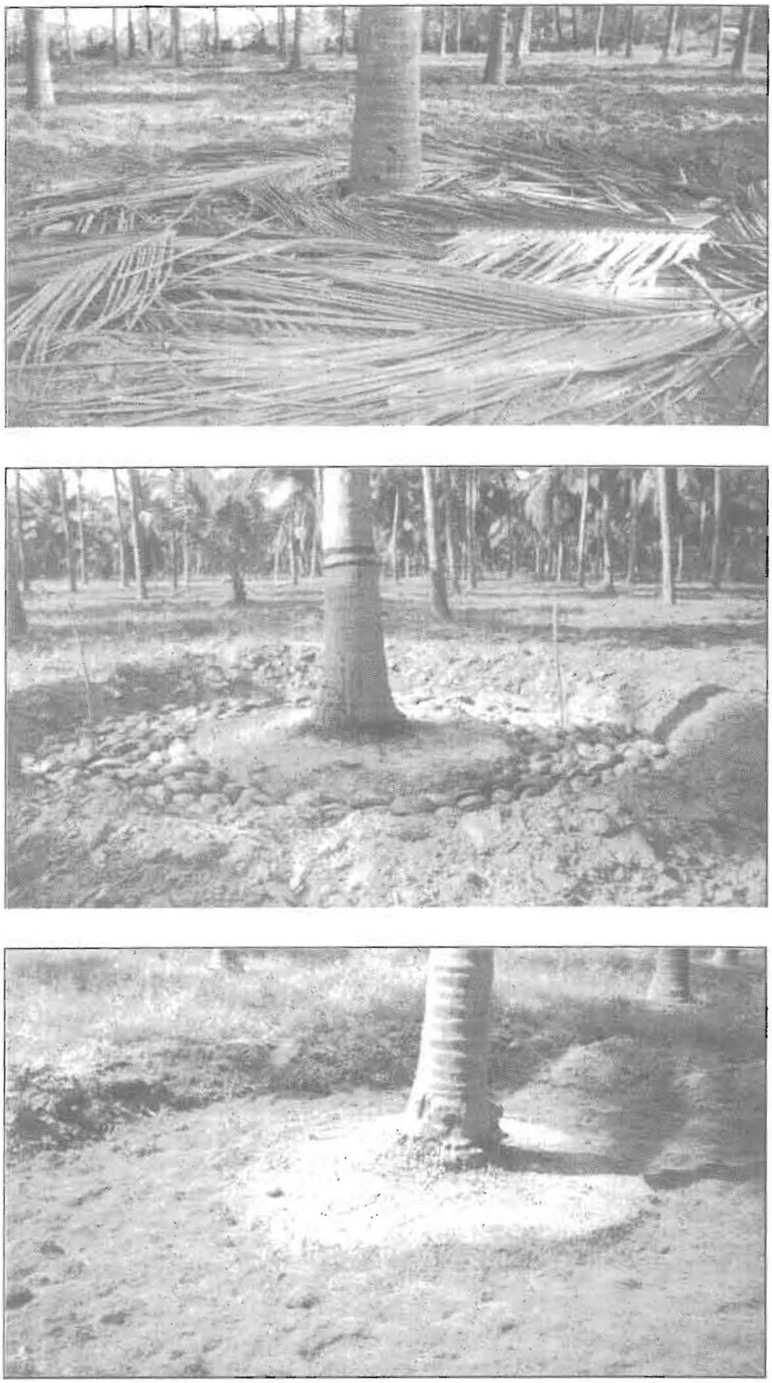

Figure 13.1: Soil and Water Conservation in Coconut Basins. (a) Mulching with coconut leaves, (b) Burial of coconut husk, (c) Burial of composted coir pith.

least in the coconut + cocoa mixed cropping system compared to the monoculture of coconut (Varghese *et al.*, 1978). Soil moisture conservation through leaf mulching, husk/coirpith burial in basin enhanced coconut yields in different agro-climatic regions (Figure 13.1) (Naresh Kumar *et al.*, 2006).

3.2. Moderating Temperature and Moisture Content in Soil

Coconut is being cultivated in tropical regions where temperature is high and in summer month's evaporation is also higher. Apart from moisture retention the organic materials can also bring down the soil temperature to the optimum level. It is well known phenomenon that using husk, leaves and other waste materials as a mulch in coconut garden will conserve the moisture as well as reduces the incident of sun rays reaching the earth surface. In coconut monocrop drip irrigation and mulching reduced the temperature to the extent of 4.3°C compared to unmulched rainfed crop at 15 cm depth in littoral sandy soil (Maheshwarappa *et al.*, 1998).

Adopting cropping system by growing intercrops in coconut garden has reduced the soil temperature as compared to coconut monocrop. Among intercrops, grass cultivation recorded lowest average temperature (26.5°C) followed by pineapple (27.1°C), vegetables (28.7°C) and monocrop has recorded highest average temperature (29.3°C). At the same time average maximum soil temperature in open place where no cropping is practiced was 36°C and minimum was 29.3°C (Subramanian *et al.*, 2013).The moisture content in soil is most important for growth and production of any crop. The technologies generated should also help in maintaining higher soil moisture in soil. The burial of organic materials and growing intercrops in coconut garden has helped in maintaining higher moisture level (5-7 per cent) as compared to control (3 per cent) during the crop growth period (Shivakumar, 2016). In another study, the available soil moisture under drip mulch was higher by 22.2 to 28.8 per cent compared to drip without mulch. In basin irrigation also, on fourth day after irrigation, the available soil moisture; stored in the mulched condition was 36.8 to 37.6 mm and it was 18.2 to 19.9 mm under unmulched condition, indicating the moisture depletion higher by 28.6 to 30.7 per cent compared to moisture present on first day after irrigation (Maheshwarappa *et al.*, 1998).

On the farm scale, shade can be essential for certain crops, particularly in the tropics. Cocoa and banana are important intercrops in coconut and arecanut garden have shady canopies they grow beneath. Trees in particular are also important for filtering air pollution and particulates, and help create a protected and nourishing microclimate in most places they are planted. Simulation analysis indicated that negative impacts of climate change can be overcome by adaptation strategies such as assured irrigation through drip system coupled with soil moisture conservation and by providing fertilizers/nutrients through organic and inorganic source in doses higher than those currently applied by the farmers. Such measures also maximize the positive impacts of climate change. Farmers who adopted soil moisture conservation practices or drip irrigation could reduce the drought impact on their plantations. In drought affected coconut gardens, farmers could grow short duration pulses, oil seeds and millets for their sustenance.

In Kerala, providing more fertilizers along with summer time irrigation and following soil moisture conservation practices could further improve the positive gains due to climate change by 7 to 21 per cent in different scenarios. In Karnataka, West Bengal, Gujarat, Maharashtra and Odisha assured irrigation and providing more fertilizers could not only off-set the negative impacts but could also result in higher yields.In North-Eastern States, providing summer irrigation and even low dose of fertilizers could further improve (in the range of 10-33 per cent) the positive impacts of climate change. Coconut plantations in islands, if managed scientifically by proper spacing, canopy management, summer irrigation and even with low dose of fertilizers the productivity could be enhanced to an extent of 2-25 per cent.

4. Conclusions

It is clear that climate change will have negative effects on coconut plantations due to increased temperature and water stress. However, coconut plantations can also be used to mitigate climate change which is an environment service by acting as C Sinks to absorb CO_2 from the atmosphere and control global warming while giving an additional income to the growers through C trading. In areas of poor performance of coconut yield, it is advisable to go for coconut based farming system due to a number of advantages like high productivity, maximum biomass utilization, increases in soil microbial population, and increases in soil water holding capacity which is helpful in plant growth and survival during low rain fall and drought condition. This is why we can call CBFS as permanent agriculture. Soil moisture conservation through leaf mulching, husk/coirpith burial in basin enhanced coconut yields in different agro-climatic regions (Naresh Kumar et al., 2006).

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