Climate change adaptation in coconut: A coconut based farming system approach

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Climate change

Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors that include oceanic processes (such as oceanic circulation), variations in solar radiation received by Earth, plate tectonics and volcanic eruptions, and human-induced alterations of the natural world; these latter effects are currently causing global warming, and "climate change" is often used to describe human-specific impacts.

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial runoff, precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects. Assessment of the effects of global climate changes on agriculture might help to properly anticipate and adapt farming to maximize agricultural production.

At the same time, agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide, but also by altering the Earth's land cover, which can change its ability to absorb or reflect heat and light, thus contributing to radiative forcing. Land use change such as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide; agriculture itself is the major contributor to increasing methane and nitrous oxide concentrations in Earth's atmosphere.

There is a broad consensus that climate change is occurring, and that it is linked to a build up of greenhouse gases in the atmosphere enhancing the natural greenhouse effect. Carbon dioxide (CO_2) is, by far, the largest contributor to greenhouse effect. In addition to increased CO_2, with climate changes, the plants have to adapt their ways to a new environment – in most cases warmer and possibly with the periods of extreme rainfall and drought.

Coconut response to climate change

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 stabilizing yields 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% humidity (Child 1974, Murray 1977). The generally recommended levels of major nutrients like NPK is at 500 g N: 320 g P2O5: 1200 g K2O per palm/year.

The recommended irrigation levels are 200L/palm once in four days or @ 66% 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 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% during 2020, up to 16% in 2050and up to 36% in 2080 over current yields only due to climate change. However, in east coast yield is projected to decline by about 2% in 2020, 8% in 2050 and 31% 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, Orissa and Gujarat. Coconut has adaptive strategies to withstand or overcome the stress conditions at morphological, physiological, biochemical, anatomical and molecular levels. In this paper 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.

Drought

Drought stress affects coconut production in almost all coconut growing countries, since it is mainly a rainfed plantation. Hence, the productivity is low in these areas by 50% of irrigated gardens. Coconut faces summer dry spells each year apart from the frequent occurrence of drought years. This is projected to increase further as the long term climatological data for 140 years in the humid tropics of India indicate cyclic pattern in rainfall with a declining trend in annual and southwest monsoon rainfall during

the past 60 years. Being perennial in nature, coconut palm had a long duration from the initiation of inflorescence primordia to nut maturity (~44 months) with longer pre-fertilization period (~32 months) than post-fertilization (12 months) period. Hence, the impact of drought occurring at any of the critical stages of the development of inflorescence affects nut yield not only in current year but also in next three years to follow, thus makes the problem more severe.

Response to soil moisture

Coconut has been considered as extravagant in water consumption. It is estimated that the water consumption by tall coconut in India as 115 L day-1 in summer and 55 L day-1 in winter. Studies with dwarf varieties have suggested a daily water consumption of 8-12 L palm-1 in the first six months after planting in the field, 12-28 L palm-1 from 7 to 12 months and 30-55 L palm-1 from 13 to 18 months. Compared to the tall varieties, some evidence suggests that dwarf varieties use water more extravagantly due to its elevated transpiration rate (IRHO-CIRAD, 1992), greater number of stomata per unit leaf surface (stomatal frequency) and lower wax content on the leaf surface, as well as a poorer stomatal control of water loss. Tall varieties, in contrast, show a more conservative water use.

Temperature:

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. The ideal mean annual temperature for coconut growing is usually considered to be in the region of 29°C (27 - 32°C), with abundant sunshine and a well-distributed annual rainfall. 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. Preliminary investigations involving the Infocrop-coconut model revealed that the coconut production in west Coast is less affected compared to East Coast with future climate scenarios (A2, B2 and A1B).

CO_2 concentrations

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. unpublished data). Elevated CO_2 to certain extent could offset the negative effect of temperature in coconut. The stimulatory effect of CO_2 under drought was less and it could increase the biomass by only 8% at 700 ppm CO_2. Crown initiation and crown growth in coconut are very sensitive to climate change variables. Crown growth rate was approximately 2 cm/day with 550 and 700 ppm CO_2 as against 1.8cm/day of plants grown in ambient condition. The higher growth rate of plants under elevated CO_2 was closely associated with the photosynthesis (PN). Photosynthesis was highest 14.4 at 700 ppm CO_2 as against 10.14 under ambient condition. Application of 150% RDF with 700 ppm CO_2 had an additive effect on PN and it increased to 16.3 umol/m2/s. Chlorophyll fluorescence data measured in the same leaf where the PN was measured indicated that Fv/Fm (dark adapted values) which reflects the potential quantum efficiency of PSII, was on par in ambient and elevated CO2 plants

Interaction effect of CO_2, high temperature and drought

The interaction effect of climate change variables CO_2 and elevated temperature (ET) with drought and nutrients on growth and development of coconut seedlings was studied in an Open Top Chamber (OTC) at CPCRI, Kasaragod. High temperature (3 oC above ambient) decreased the biomass by 10%. High temperature in addition to drought had a compounded effect and reduced the biomass by 16%. To certain extent the elevated CO_2 could offset the negative effect of temperature in coconut. The stimulatory effect of CO_2 under drought and high temperature was less and it could increase the biomass by only 8% with 700 ppm CO_2.

Spindle leaf initiation and its growth is slow at ET. It was only 1.3 cm/day with ET and 1.7 cm/day with elevated CO_2+ET as against 1.8cm/day of plants grown in ambient condition. Similarly, spindle leaf growth rate significantly reduced in drought plants. Leaf splitting was faster when plants were grown under elevated CO_2 and was slow with drought and ET treatments. The stomatal conductance and the transpiration on the other hand were high in ET treatments 0.216 and 5.63 as against 0.125 moles/m2/s and 2.58 moles/m2/s with 700 ppm CO_2 respectively indicating better intrinsic tolerance of plants to water limitation under elevated CO_2 concentration. The WUE was low at ET (2.28) and increased to 2.56 g/litre ET+CO_2 indicating higher CO_2 could offset the effect of ET in coconut. Similarly, under drought too the WUE was the highest at 700 ppm CO_2 (2.70) and it was the least at ET (2.144).

Adaptation strategies of coconut to climate change

Higher yield realization with the adoption of 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, pomegranate, custard apple, cocoa, nutmeg, clove etc 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 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.

CBFS require less fossil fuel inputs, both from mechanization and from chemical fertilizers. Implementation of food forestry around the world could reduce fossil fuel use in transport dramatically by increasing local production. Coconut farming systems have dramatic powers to stabilize eroding farmland, especially sloping lands. Practices like using nitrogen fixing perennials, plowing, and intensive livestock rotation have fantastic soil building abilities. Plantings of useful trees can protect coastlines from damage caused by increased storm activity.

On the farm scale, trees and perennials can dramatically improve rainwater infiltration and groundwater recharge. At both the farm and regional scale, permanent agriculture can break the flood-drought cycle by soaking up and slowly releasing water like a sponge, providing a longer season of moderate water flow in streams and rivers downstream. Erosion control and slope stabilization means less siltation and nutrient runoff in streams, having effects from local waters to offshore coral reefs. 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% in different scenarios. In Karnataka, West Bengal, Gujarat, Maharashtra and Orissa 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%) 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%.

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.