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Impact of Climate Change on Horticulture in Konkan, Maharashtra : Activities and Strategies

Tapas Bhattacharyya, P.M. Haldankar, P.C. Haldavanekar, M.M. Burondkar, B.R. Salvi and E.B. Chakurkar[1]
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra
[1]ICAR - Central Coastal Agricultural Research Institute, Ela, Old Goa

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Abstract

Area along the vast coastline of India represents variety of natural ecosystems and diversified conditions in terms of soil, climate, and water resources which exert varied influence on agriculture, horticulture, forestry, animal and fishery sectors. Coastal ecosystem is vulnerable and more sensitive even to slight changes in climate demanding disaster management studies in the field of agriculture against climatic vagaries. Konkan is the western coastal strip of Maharashtra, India with an area of 2.979 million hectares (Mha), with major two landscapes namely, the western slope of Western Ghats and the narrow coast line. The sectoral and regional analysis for 2030s in India predicts climate change in both these two landscapes compared to 1970s in a broad way. Typical agro-climatic conditions provide ample scope for horticulture in the region with special reference to Alphonso mango and cashew nut as rainfed crops. The five-to-six fold impact of climate on mango and coconut in Konkan, Maharashtra is discussed. Modelled studies on coconut and the effect of climate change on its yield are also analysed in this part of coastal India. Since climate change and warming studies require huge datasets for the past and present scenarios to build the predicted incidences, there is a need to sharpen the Soil Information System for Horticulture (SISHORT) as a way forward.

Key words: Coastal ecosystem, Konkan, horticulture, SISHORT

Generalities

Peninsular India is bounded by water on 3 sides with coastline running over a distance of 7,500 km. It is seventh longest in the world and 1/5th of the population lives along the coast with 3 metropolitan cities. The areas along the vast coastline of India represent variety of natural ecosystems and diversified conditions in terms of soil, climate, and water resources with profound influence on agriculture, horticulture, forestry, animal and fishery sectors. Problems in the agriculture and allied sectors in coastal areas are different from the other geographical areas. In the coastal areas, horticultural crops and livestock production, with special reference to fisheries and aquaculture, often dominate over the traditional field crops. Coastal areas, in general, are warm and humid which favour raising a broad array of commercially important field and horticultural crops. The coastal region provides greater scope for integration of agriculture, horticulture, forestry, animals, fisheries and agricultural engineering for the improvement of socio-economic conditions of farmers (**Figure 1**).

Coastal ecosystem is vulnerable and more sensitive even to slight changes in climate. It makes a good case for studies for disaster management against climatic vagaries. Research organisations namely, State Agricultural Universities (SAUs), Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR) and others are researching on Indian coasts to address various issues which principally include climate change and warming. Nearly 56 organisations are working on Indian Coasts of which 26 are on the West and 30 on the East (**Figure 2**) coasts. For the studies on a sectoral and regional analysis for 2030s regarding climate change in India, nearly 18 institutions and 43 researchers participated (**Figure 3**).

Figure 1. Coastal areas in India covers ~7,500 km. (Source: Anonymous, 2019)

tapas11156@yahoo.com

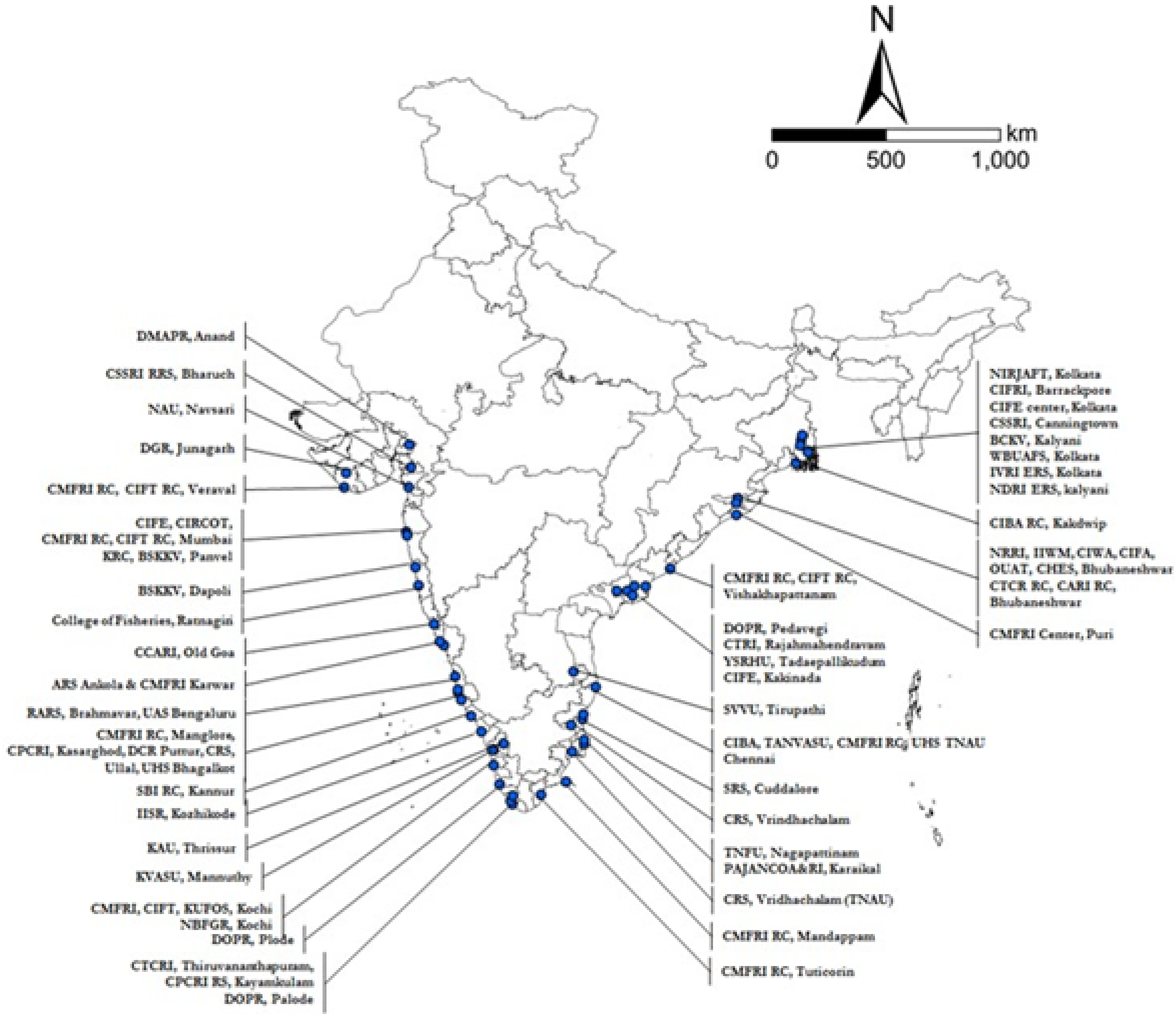

Figure 2. Various organisations on the Indian Coast engaged in agriculture and other researches (Source: Anonymous, 2019)

Konkan (Konkan Coast) represents a rugged terrain on the West Coast of India. It extends from the Gulf of Cambay in the North to Southwards all along the Western seaside till it reaches the Kanara coast at Karwar (district) in Karnataka.

Konkan is the western coastal strip of Maharashtra with an area of 29,79,000 hectares (2.979 Mha). It extends from Gujarat's South border to Goa's North border. It is flanked by the Western Ghats (Sahyadri) on east and Arabian Sea on the west. This dominantly coastal part of Maharashtra comprises of Sindhudurg, Ratnagiri, Raigad, Thane and Palghar - Mumbai suburban districts. Maharashtra state has eight agro-climatic zones out of which four occur in the Konkan (**Figure 4**). Rainfall distribution across Konkan is shown in **Figure 5** with 3,794 mm mean annual rainfall (MAR) in Nilleli and 2027 mm minimum MAR at Repoli. If this criterion of rainfall is considered as the driving force for planning agriculture with special reference to horticulture, Konkan may then have nine (9) agro-climatic zones. This is again a subject of research. Konkan, Maharashtra presents the green and luxuriant vegetation, biodiversity and natures' beauty and bounty (**Figure 6**).

Land Use in Konkan, Maharashtra

The Konkan region is distinguished from rest of Maharashtra state by virtue of its distinct agroclimatic conditions, soil types, topography, location, crops, cropping pattern, land holdings and socio-economic conditions of the farmers. The landscape in Konkan is characterized by rugged terrain, forested hills and barren plateaus. Barren, unculturable and cultivable wastelands cover 27% area which may be used for horticultural expansion (**Figure 7**). Forest is a predominant landuse in Konkan region. However, the figures here do not justify it as these show only the recorded government forest area. The landuse of the districts in Konkan is shown in **Figure 8**. Most of the forest area, especially in Ratnagiri

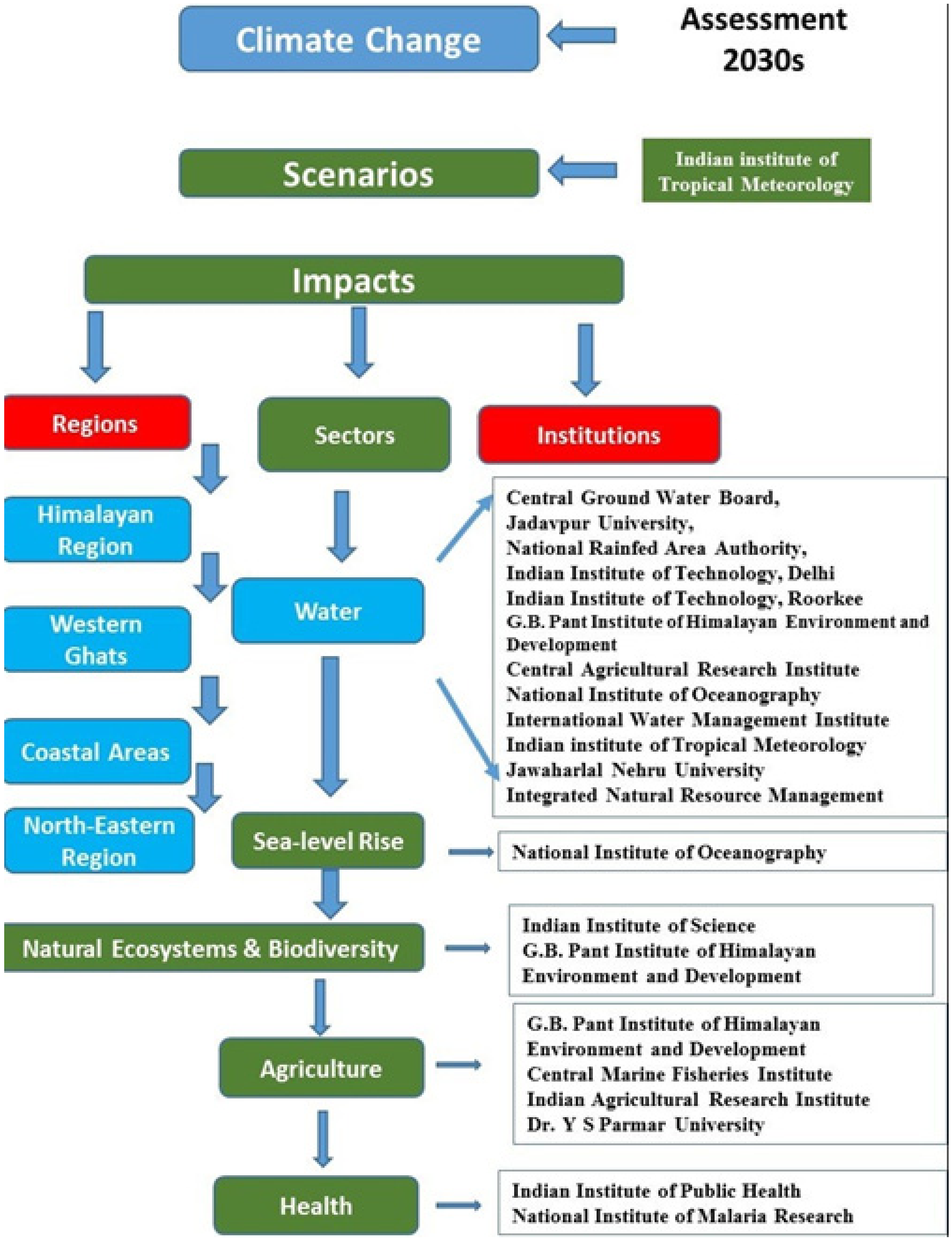

Figure 3. The 4x4 climate change assessment: Institutional arrangement in India (Source: Anonymous 2010)

and Sindhudurg districts is privately owned. In the undivided Thane district, relatively less land is available for horticultural expansion compared to other districts of Konkan (**Figure 8**). Rapid urbanization is also a separate land use in this district. In Raigad district, there is a good scope for olericulture and floriculture; raising fruits and plantation crops constitutes an ideal option. Judging by the threat of climate change and also the driving popular food habits of this region, fisheries are an important component and should be encouraged in Raigad district (**Figure 8**). In contrast, proportion of barren and uncultivable land increases considerably in Ratnagiri district. Most of these lands are under fruit orchards as a part of extending area under horticulture (Bhattacharyya et al., 2019b) (**Figure 8**). A good size of private forest has already been converted to fruit orchards. In Sindhudurg district, on the other hand, diversity of horticultural crops is the highest. There is still a scope for development (**Figure 8**). New developed technologies with respect to intercropping of spices in plantation crops and

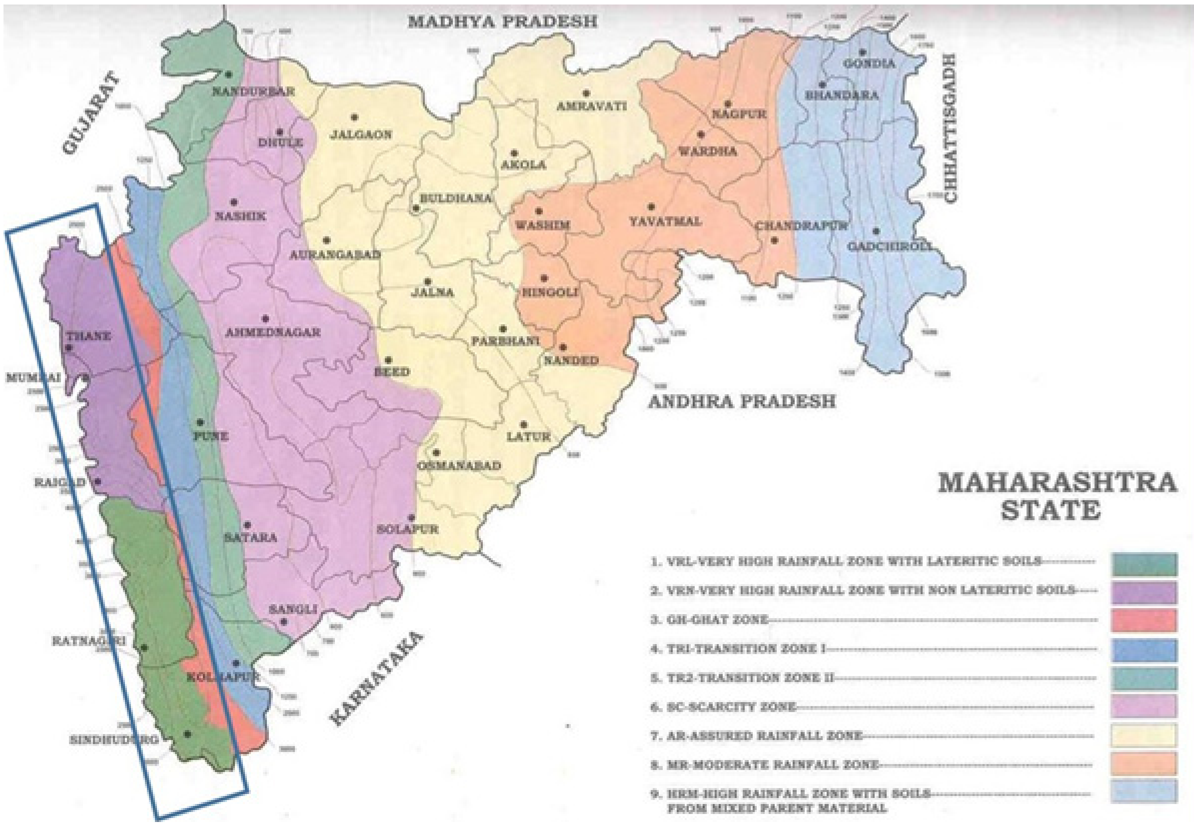

Figure 4. Agro-climatic zones of Maharashtra. The rectangular box indicates the zones falling in Konkan area

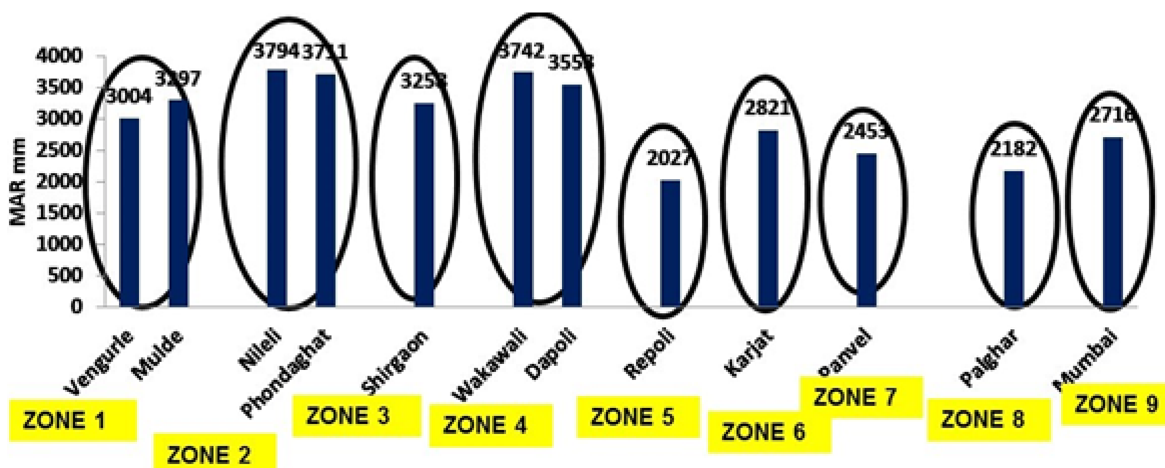

Figure 5. Rainfall distribution in Konkan, Maharashtra and probable agro-climatic zones in this region

seasonal vegetables are the intercrops in present orchards which give benefit of additional income with sustainable production.

Horticultural Importance of Konkan

Strategic advantages in terms of climate, and topography favour horticulture in Konkan. Hilly terrain, well-drained red soils, assured rainfall in monsoon, high relative humidity, mild winter and summer put this region in a favourable situation to encourage horticulture with its various types. There are, however, limitations. These include fragmented land holdings, inaccessible roads for transportation of produce to big cities, various socio-economic factors, and infrastructure. Other important factor is limitations for seasonal field crops in this region. Sustenance through perennial horticultural crops is also a matter of concern in this region.

Figure 6. Typical landscape of Konkan, Maharashtra

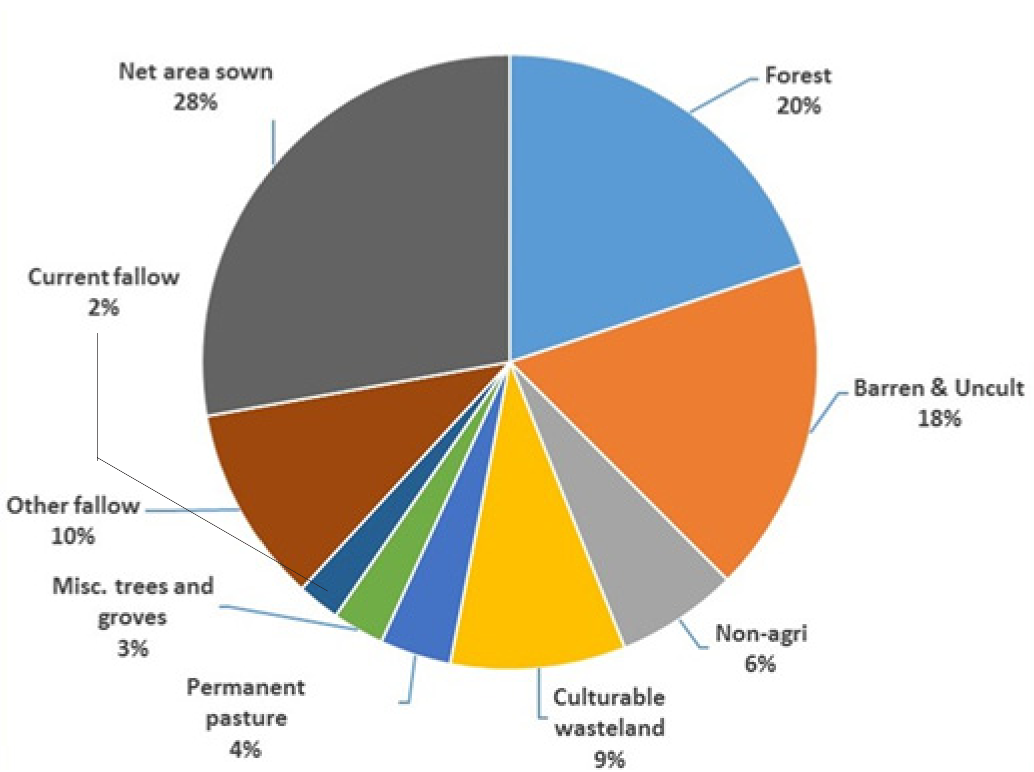

Figure 7. Land use of Konkan, Maharashtra

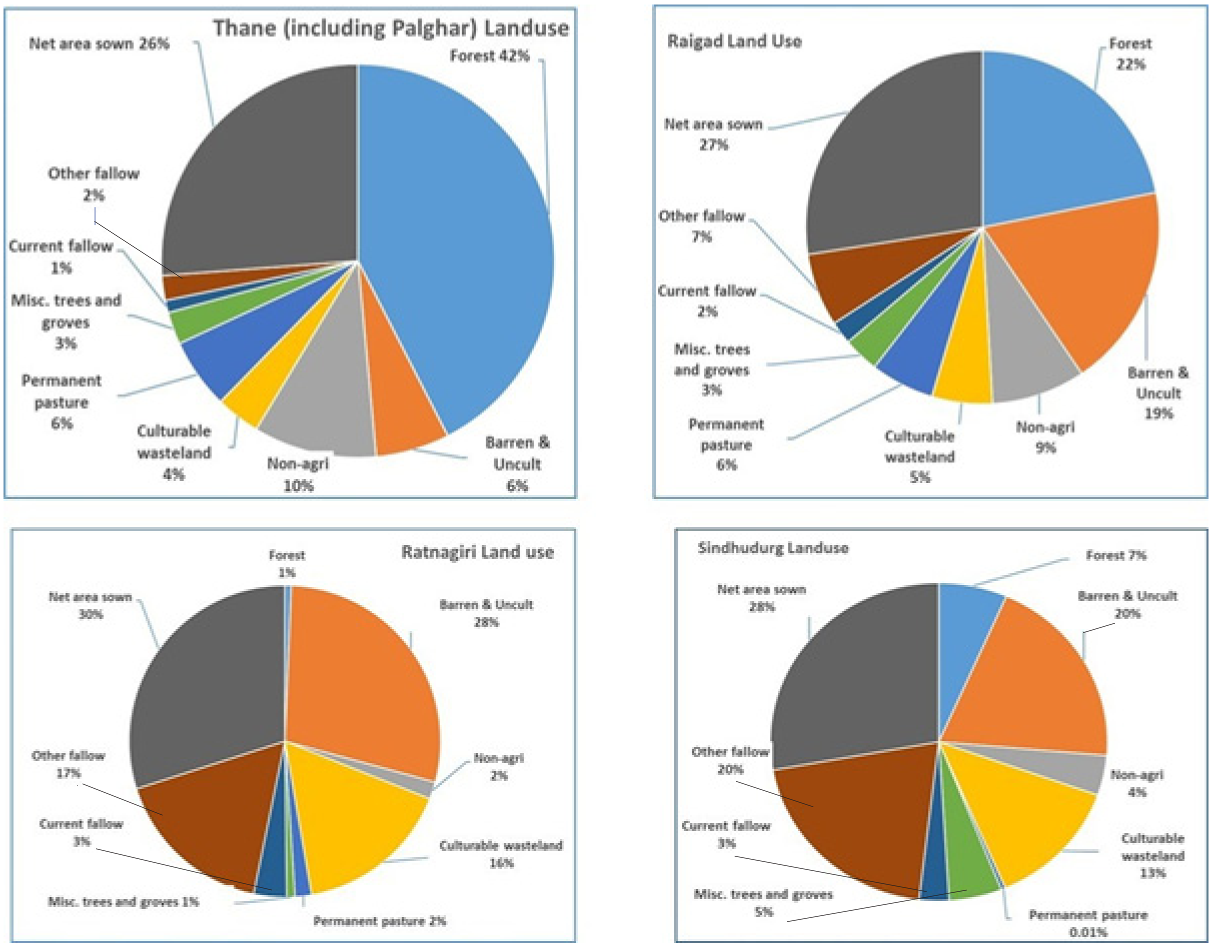

Figure 8. Land use of different districts in Konkan, Maharashtra

Major horticultural crops raised/grown in Konkan are shown in **Table 1**. In fruits, main crops are mango, cashew, coconut, arecanut and sapota. Among vegetables, okra, chilli, watermelon, yard long bean, cucurbits and amaranth are important. In spices, there are many options *viz.* black pepper, nutmeg, cinnamon, clove, turmeric, ginger and betel leaves. For the flower sector, North Konkan is gradually picking up mostly for jasmine species and lily. Konkan is also termed as a fruit basket. Mango, cashew, coconut, sapota, etc.,

Table 1. Major horticultural crops in Konkan, Maharashtra in descending order of area occupied

Fruits	Vegetables	Flowers	Spices
Mango	Okra	Rose	Black pepper
Cashew	Chilli	Jasmine	Nutmeg
Coconut	Brinjal	Marigold	Cinnamon
Sapota	Bitter gourd	Gerbera	Clove
Arecanut	Cucumber	Gladiolus	Turmeric
Kokam	Ridge gourd	Chrysanthemum	Ginger
Banana	Cowpea	Tuberose	Betel leaves
Jackfruit	Lablab bean	Aster	
Jamun	Brinjal	Gaillardia	
Aonla	Bottle gourd		
Bullock's heart	Onion		
Lemon			
Pumello			
Papaya			
Pineapple			

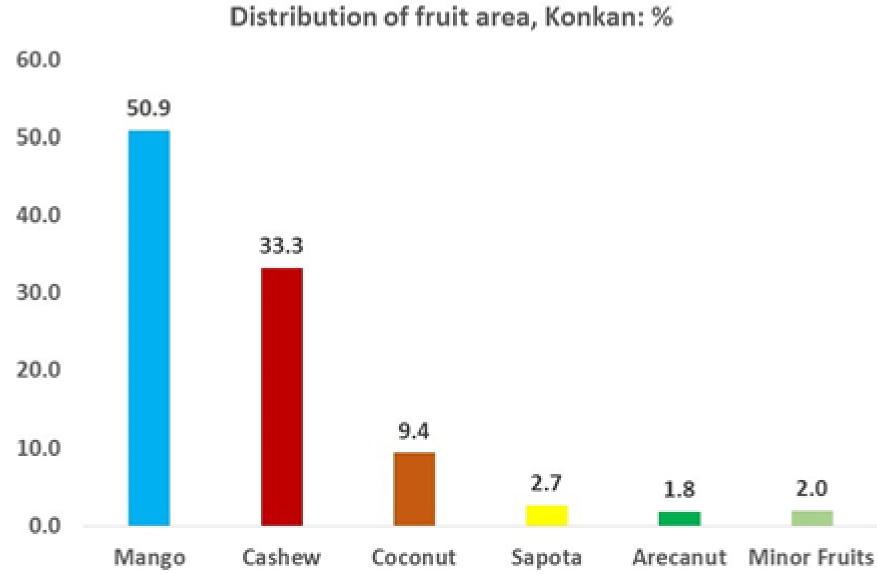

Figure 9. Distribution of fruit area in Konkan, Maharashtra

are the major fruit crops occupying nearly 94% area (**Figure 9**). Sapota is a major fruit crop in Thane district. But some of these areas are also being used for growing vegetables and flowers. Proximity to metro cities constitutes a boon for the farmers. Raigad district also grows a few fruit crops like cashew, coconut, and sapota. Mango dominates with more than 75% area under it. In Ratnagiri, mango by far is the dominant fruit crop. Cashew comes next, and coconut and others are also catching up. In Sindhudurg, cashew dominates followed by mango and other fruits (**Figure 10**).

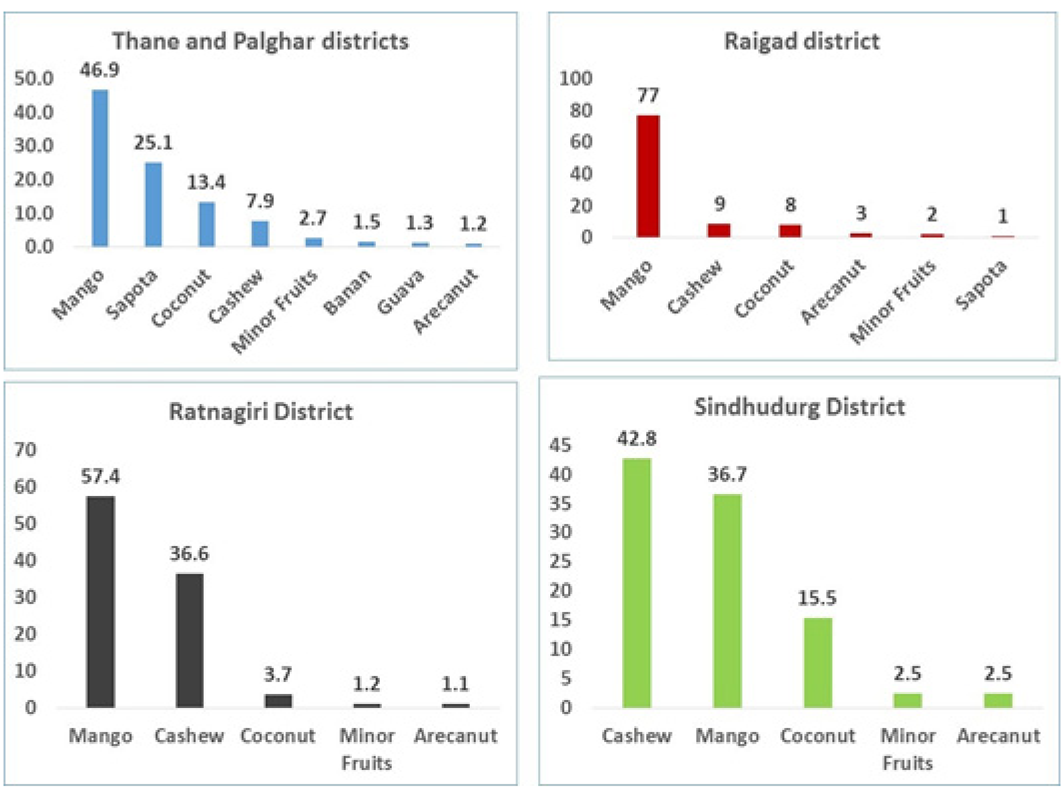

Figure 10. Distribution of fruit area in different districts in Konkan, Maharashtra

Climate Change in the Western Ghats and Indian Coasts

Konkan, Maharashtra has two major landscapes. One is the western slope of the Western Ghats and the other one is the narrow coast line. The sectoral and regional analysis for 2030s for India predicts climate change in both these two landscapes compared to 1970s in a broad way (Anonymous, 2010).

Mean annual rainfall (MAR) is likely to vary from 935±185.33 mm to 1794±247 mm in the Western Ghats (increase of 6–8%). The minimum temperatures may rise by 2.0 to 4.5 °C, with minimum increase in those parts of Karnataka that lie in the Western Ghats. Within the region bordering the state of Kerala, the maximum temperature is likely to rise by 1 to 3 °C. The number of rainy days is likely to decrease along the entire western coast, including the Western Ghats. Increased intensity of rainfall by 1–2 mm day^{-1} may be a probability. An increase in rainfall in the range of 1-5 days in the Western Ghats (Karnataka region) is also predicted.

So far as the coastal region is concerned, rainfall is predicted to remain between 858±85.8 and 1280± 204.8 mm in the 2030s in the ***eastern coast*** which shows an increase between 0.2 and 4.4%. Projections for the western coast indicate a variation from 935±185.33 mm to 1794±247 mm (6–8% increase). The rise in minimum temperatures along the eastern coast is predicted to be lower than that in the western coastal region. The projected change in minimum temperatures along the eastern coast may range from 2.0 °C to 4.5 °C. Higher range of change may be limited to Tamil Nadu coast. The change in maximum temperature may range between 1 °C and 3.5 °C. The western coast is predicted to experience similar extremes in temperature as in the Western Ghats. Number of rainy days are likely to decrease by 1–5 days in the east coast. Slight increase along the Odisha coast is also predicted. The intensity of rainfall is likely to increase (1-4 mm day^{-1}). Extreme precipitation events for the west coast will happen with similar probability as in the Western Ghats (Anonymous, 2010).

Amidst global climate change phenomenon, there are climatic vagaries, specifically in Konkan. This region has nevertheless a stable average (25.32 °C), minimum (19.81 °C) and maximum (30.84 °C) temperature along with the annual rainfall of 3649 mm and 97 rainy days in a year. There is a general trend in major climatic factors *viz*. i) increasing annual rainfall, ii) delayed and extended rainy season, iii) increasing unseasonal rains, and iv) increasing mean annual temperatures. Also, a general trend in two important weather events namely increase in maximum one-day precipitation and frequency of warm days in this region are observed.

Nearly 40 years data show the reduced decadal average rainy days, increased total rainfall with higher intensity of rains in a few days.

Decadal average shows that rainy days are reducing in Konkan. Total rainfall is increasing with higher intensity of rains in a few days (**Figure 11**). Aberrations in total rainfall in Konkan and its frequency show increasing trends (**Figure 12**). The mean annual rainfall in Konkan is 3650 mm. During 1973, it was around 4000 mm and it increased to about 4600 mm in 2016. The trend of maximum, minimum and average temperature is also exhibiting rising trends (**Figure 12**). Maximum temperatures have risen by approximately 0.23 °C since 1998 when the trend line crossed the normal maximum temperature. For the minimum temperature, there has been a decreasing tendency compared to the past values. More recently, however, even the minimum temperature has increased beyond the normal, although the trend line is still to cross the normal minimum temperature (**Figure 12**). So far as the average annual temperature is concerned, the trend line crossed the normal value during 2010. Since then, there has been an increase of 0.2 °C average annual temperature in this part of Maharashtra (**Figure 12**). It is with this background of climatic vagaries in Konkan, Maharashtra, attempt in this study has been made to examine how horticulture is placed here and how our policies can beat the trend of warming in this coastal ecosystem.

Major Fruit Crops of Konkan

The typical agro-climatic conditions provide ample scope for horticulture in the region. Konkan is traditionally famous as homeland for the commercial cultivation of world-famous Alphonso mango and cashewnut as rainfed crops A comparison of the major fruit crops in Konkan with the national average is shown in **Figure 13**. There is more scope for increasing the production of mango, cashew, coconut and banana plantations. So far as cashew is concerned, Konkan is maintaining its position as the leader in terms of both quality and productivity.

Effect of Climate on Mango

For mango, the requirements of climate and soils match the situation prevailing in Konkan. Climatically, a tropical and sub-tropical climate with an optimum temperature of 24-30 °C is suitable. The sunshine critical for leaf development, maximum stomata conductance, leaf gas exchange, and greater net CO_2 assimilation is at times limiting. Mango needs deep and well drained soils with sandy to clay loam

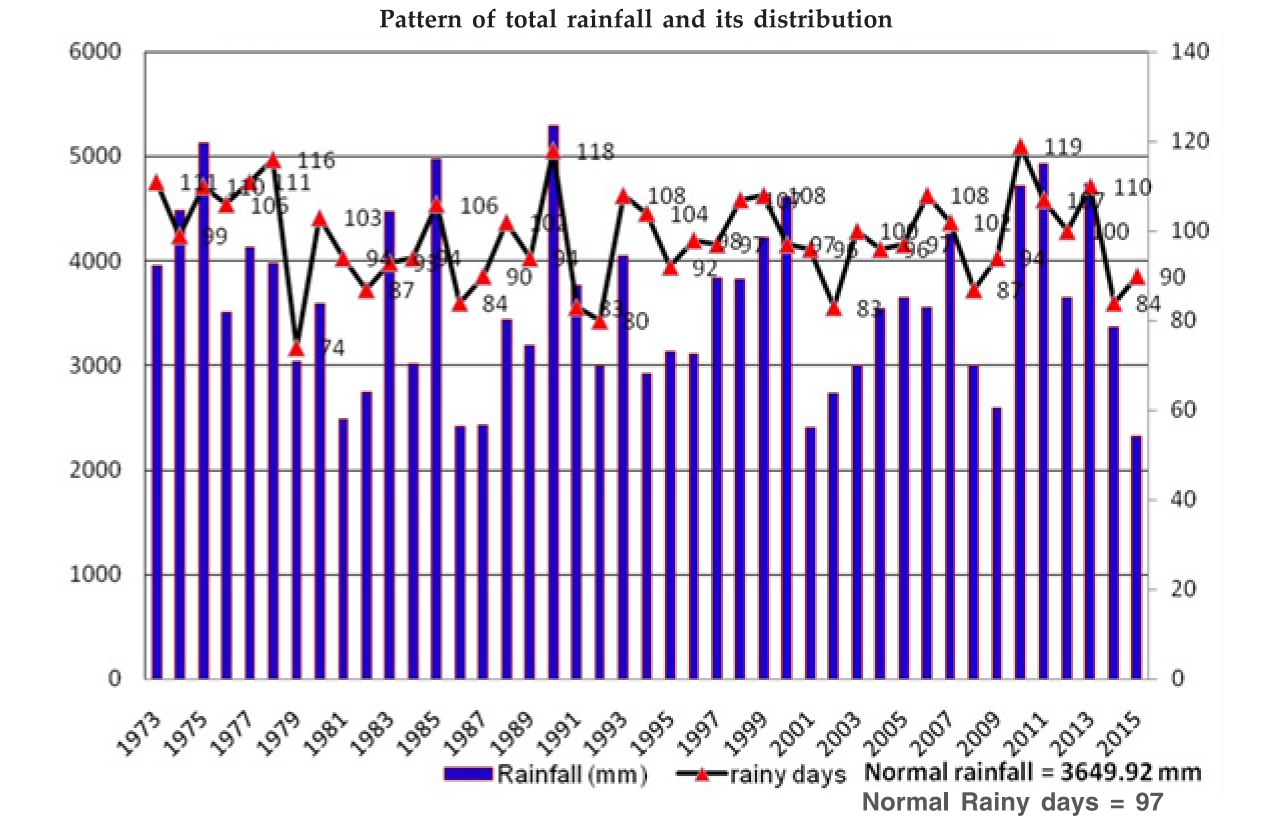

Figure 11. Total rainfall and its distribution in Konkan, Maharashtra

texture with an optimum pH of 5.5 to 7.0; it can, however, stand up to a pH of 8.5 (Bhattacharyya et al., 2018a; Burondkar et al., 2018). **Figure 14** shows the influence of climatic parameters on mango at three different stages of growth. The left side of each box shows the beneficial zone and as we traverse to right we enter in harmful zones of mango growth. High temperature and high rainfall are good but high winds and low humidity prove harmful for its vegetative growth. For flowering and fruit yield stages, the scenario changes. The weather vagaries sweeping the Konkan region have disturbed the crop phenology, especially the vegetative growth dynamics eventually affecting the reproductive phenophases. The recent climate vagaries like prolonged rainfall, extended low temperature, sudden increase in day temperature have been recorded to alter the normal phenology of crop which has disturbed not only production cycle but also deteriorated the quality of production. The impact of climate on mango in Konkan, Maharashtra manifests itself fivefold in the form of i) transformation of reproductive buds into vegetative buds, ii) multiple reproductive flushes, iii) early or delayed flowering, iv) variations in fruit maturity, iv) abnormal fruit set, and v) fruit damage and development of spongy tissues.

Studies conducted by Burondkar et al. (2012) on environment and physiology on Alphonso mango in Konkan indicated the negative effects of changing climatic factors on vegetative growth and also on the flowering stages (**Table 2**). They also observed that during fruit set, maturity and ripening, some of the changing parameters may be positively beneficial. This might trigger research about developing a model of understanding for mango *vis-à-vis* climate change and also mitigating the effect of warming on mango. Such efforts will help to keep our country at the top of the ladder in terms of quantity and quality of mango. The technologies namely varietal selection, appropriate planting material and planting, regulation of flowering, prediction models for emergence of vegetative shoots as well as flowering, rejuvenation of old and senile orchards, fruit bagging for spotless fruits, precise harvesting and appropriate handling along with plant protection schedule are certainly helpful for sustainable production of quality mango under the climatic aberrations in Konkan, Maharashtra.

Effect of Climate on Cashewnut

For good performance of cashewnut, the major requirement is the warm, humid, typical tropical climate with an optimum average temperature of 24-

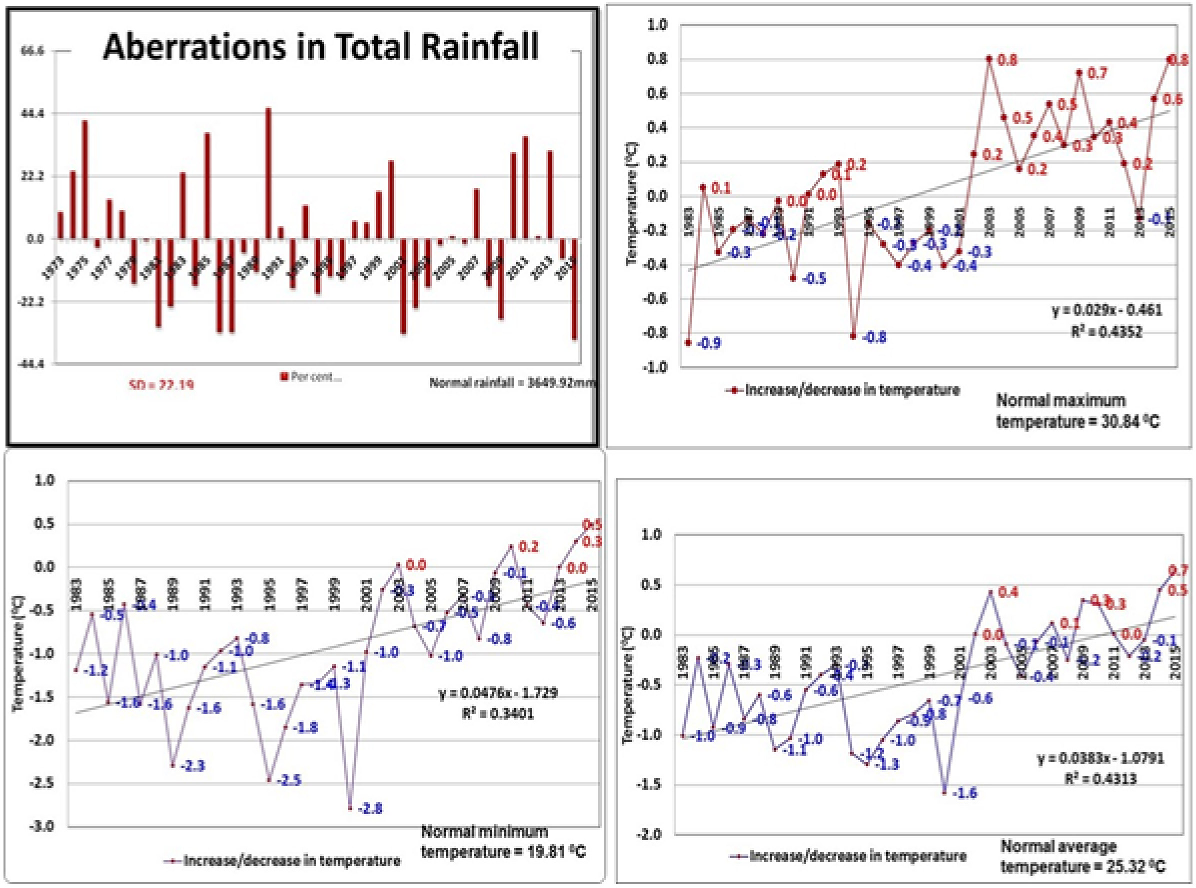

Figure 12. Aberrations in total rainfall and its frequency, in maximum temperature, trends in minimum, and average annual temperature in Konkan Maharashtra

28 ºC. Cashew needs good sunshine which is critical for its leaf development, maximum stomatal conductance, leaf gas exchange and greater net CO_2 assimilation and providing leaf saturation point of about 1000 photosynthetic photon flux (PPF). Well drained, loam to clay loam, 150-300 cm soil depth, acidic to near neutral soil reaction, non-saline soils with nearly 0.71% of organic carbon (OC) with high base saturation of nearly 60-65% are ideal for cashew cultivation. It has to be remembered that cashew grows well between elevations of 200 to 250 m above mean sea level (amsl) without any water stagnation.

Table 2. Effects of climatic parameters on mango and cashewnut

Climatic parameters	Changes	Effects		
		Vegetative development	Flowering and fruit set	Fruit growth and quality
Mango (Source: Burondkar et al., 2012)				
Temperature	Increase	Negative	Negative; Positive	Negative; Positive
CO_2	Increase	Negative	———	Positive
Drought	Increase	Negative	Negative; Positive	Negative; Positive
Flooding	Increase	Negative	———	Positive
Light	Increase	———	Positive	———
Cashewnut (Source: Salvi et al., 2016)				
Temperature	Increase	Negative	Negative; Positive	Positive; Negative
CO_2	Increase	Negative	———	Positive
Total rainfall	Increase	Positive	Negative	Positive
Rainy days	Decrease	Negative	Positive	Negative
Light	Increase	———	Positive	———

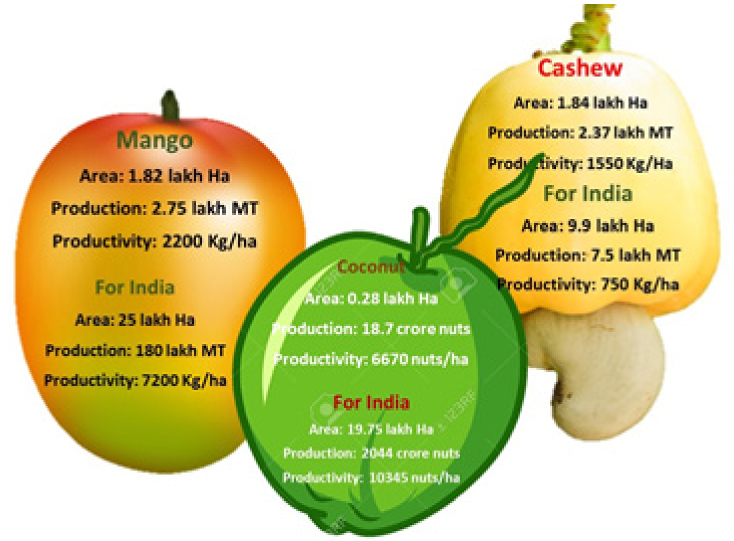

Figure 13. Major fruit crops of Konkan: a comparison with national averages

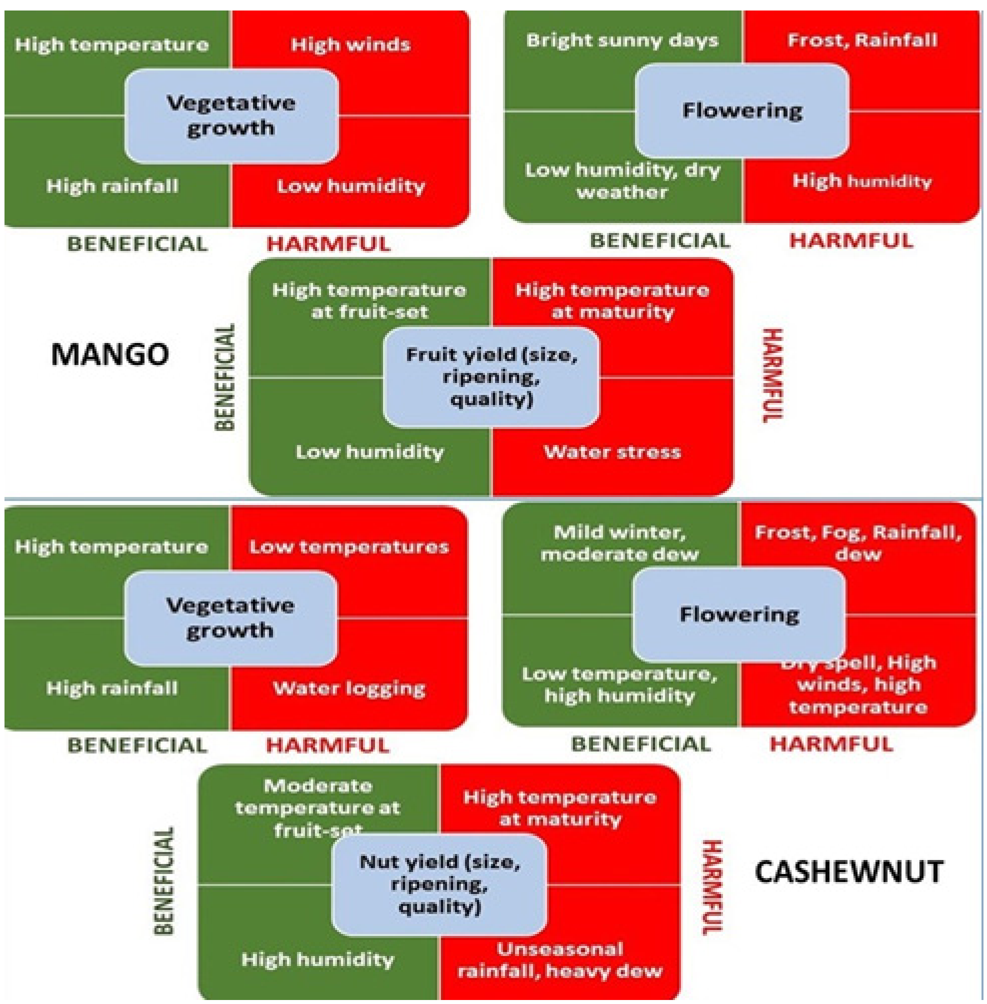

Figure 14. Impact of climate change showing different climatic factors at various growth stages of mango and cashewnut

Clay distribution in the subsurface layers plays an important role in cashew tree orchards which gradually increases down the soil depth. Despite some early reservations, it is now established that the plant available water capacity (PAWC) is a better quality parameter to adjudge soil suitability for deep-rooted agricultural crops (Bhattacharyya et al., 2018b).

Cashew requires relatively mild winter (15-20 °C) coupled with moderate dew during night for profuse flowering. High temperature (>34.4 °C) and low relative humidity (<20%) during afternoons causes drying of flowers, leading to yield reduction. All these situations result in 50-60% reductions in cashew yields. **Figure 14** indicates the effect of climate in three different stages of cashewnut trees. High temperature and rainfall are good for overall performance of cashewnut. But low temperature and water logging are harmful at least at the vegetative growth for flowering and fruit yield in the changed climate scenario. **Figure 14** indicates that the left side of each three boxes is beneficial and with shift to the right side of these boxes harmful zones begin. Rainfed cashew crop is highly sensitive to changes in the climate and weather vagaries, particularly during the reproductive phase. Unseasonal rains and heavy dew during flowering and fruiting periods aggravate the incidences of pests and diseases. The impacts of climate change on cashewnut manifest in terms of i) reduced photosynthetic activity, ii) reduced flowering flushes, iii) lesser nut retention and size, iv) increased incidences of pests and diseases, and v) fruit damage. Climate-induced yield reductions to the extent of more than 50% has led to the increase in the import of cashew from the foreign countries.

Changes in temperature and precipitation pattern together with occurrence of extreme events due to climate change are major threats to cashew sector. The maximum temperature plays a crucial role on nut size and kernel weight (Prasada Rao et al., 2010). According to Haldankar et al. (2003), relative humidity during pre-flowering phase is the main factor responsible for yield variations in cashew plantation. The unusual rains during November – December delay the reproductive phase. Unusual rains and heavy dew during flowering and fruiting intensify the pest and disease incidence as well as adversely impact the nut quality. The kernels which could not be dried due to unavailability of open sunny situations undergo the change in their kernel colour from white to cream due to surplus moisture in the raw cashewnut during storage. Aberrant weather and cashew production in coastal ecosystem was studied by Salvi et al. (2016) and Haldankar et al. (2003). Negative effects of changing climatic factors are mostly evident in the vegetative growth and also in the flowering stages. However, during fruit set, maturity and ripening, some of the changing parameters may be positively beneficial. Overall, increased soil moisture may enhance the cashew productivity (**Table 2**).

Effect of Climate on Coconut

Coconut is an important plantation crop of coastal ecosystem and is component of most of the farming households. The multi-storeyed cropping with tree spices in coconut is a solution for sustainability with greater income for small farmers to counter climatic fluctuations. Coconut requires a well distributed annual rainfall of about 1300-2300 mm, an annual mean temperature of 27-29 °C with the diurnal variation of 5-7 °C, 2000 hrs of sun shine in a year with at least 120 hrs month^{-1} and with relative humidity of >60%. The climate change scenarios have been derived from a regional climate change model PRECIS (a version of HadRM3 developed by the Hadley Centre, UK) with a resolution of 50 km x 50 km and forced by a greenhouse gas (GHG) emission scenario emanating from A1B IPCC SRES (Special Report on Emission Scenario of IPCC, 2000) (Nakicenovic et al, 2000). The 2030s is the average of the period between 2021 and 2050. All the changes in the 2030s are with respect to the average of the period 1961 to 1990s, also referred to as the 1970s or the baseline (Anonymous, 2010).

Effect of climate change and coconut yield was studied and predicted yield of crop was modelled. The analyses were done for every 1° x 1° grid for Western Ghats, north eastern region and the coastal regions with inputs of (a) observed weather data from the India Meteorological Department at 1° x 1° scale for the 1970s; (b) soil data rescaled to grid values from ICAR-NBSS & LUP and ISRIC World soil information data base; (c) crop management parameters, that is, normal crop practices as followed by farmers; (d) genetic coefficients of varieties best suitable for different regions; and (e) climate change scenarios of PRECIS A1B for 2030. Study suggests an increase of coconut yield at national level in the event of climate change with special reference to the west coast (Naresh Kumar et al., 2011) (**Figure 15**). But reduced irrigation may offset this benefit. Research was carried out using climate change model on perennial trees. In rice-wheat cropping system increase in the soil organic carbon (SOC) stocks was predicted (Bhattacharyya et al., 2007a, b). Interestingly in coconut also, increased rainfall enchanced soil organic carbon stocks an in rice-wheat system. Coconut yields are projected to increase as much as 30% in the majority of the region by the 2030s. Increase in coconut yield may be mainly attributed to the projected increase in rainfall (~10%) and relatively less increase in temperatures, apart from CO_2 fertilization benefits. However, some areas like South-

Rainfed coconut

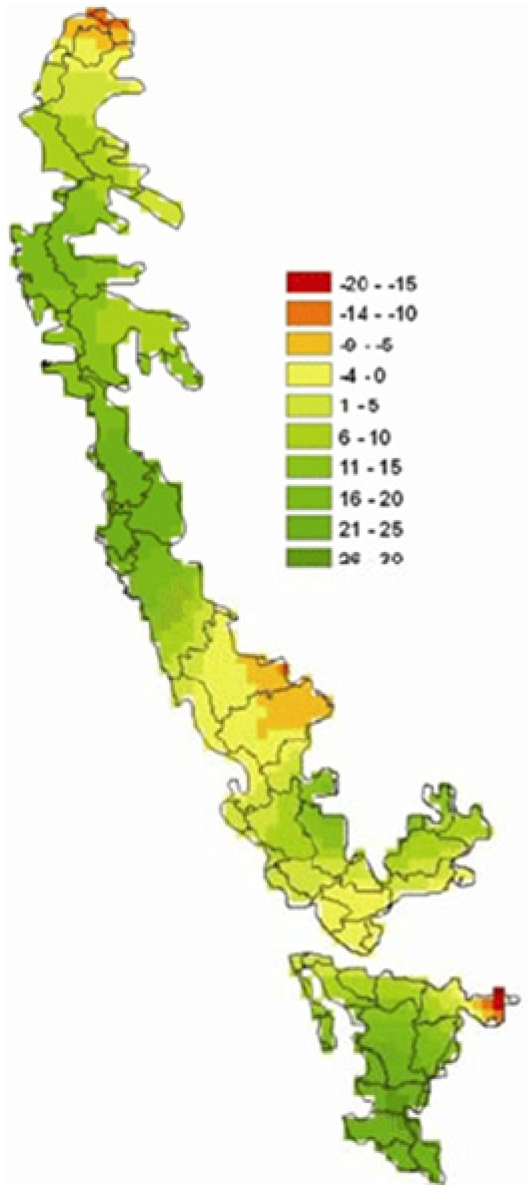

Figure 15. Projected changes in yield of rainfed coconut in the Western Ghats due to climate change in the PRECIS A1b 2030 scenario. (Values are per cent deviation from present yields) (Source: Naresh Kumar et al. 2011)

West Karnataka, parts of Tamil Nadu and parts of Maharashtra may show reduction in yields up to 24% (Anonymous, 2010).

It has been widely documented that the water deficit is a major factor affecting the physiology, growth, and productivity of coconut. Negative impact of climate change can be overcome by assured irrigation coupled with soil moisture conservation and by providing nutrients through organic and inorganic sources. Further, genetic adaptation measures like growing improved local tall cultivars and hybrids under improved crop management are needed for long-term adaptation of plantation to climate change, particularly in the regions projected to be impacted negatively by the impending climate change. Such a strategy can increase the productivity by about 33% in 2030, and by 25–32% in 2080 climate scenarios. In places where positive impacts are projected, current poor management may become a limiting factor in reaping the benefits of CO_2 fertilization, while in the negatively affected regions adaptation strategies can reduce these impacts. Thus, intensive genetic and agronomic adaptation to climate change can substantially benefit the coconut production in India (Naresh Kumar et al., 2011). Various production modules of multi-storeyed mixed cropping have been developed for small farmers through rigorous research for suitable varieties, propagation protocols, densities of various spices in coastal region of Maharashtra. The integrated multi-storeyed mixed-cropping system with tree spices namely black pepper, nutmeg, cinnamon, and kokum elevated the coconut productivity under aberrant climate of coastal region of Konkan, Maharashtra (Parulekar et al., 2020) **(Tables 3** and **4).**

Activities and Strategies

Climate change is happening and agriculture as a whole and all its growth engines should be geared up to face this challenge. Appropriate strategies need to be adopted under the climate change situations for saving horticultural crops. Conservation agriculture, using renewable energy, forest and water conservation, reforestation, afforestation, wetland protection, etc. are the most effective ways to sustain the productivity of horticulture. Modifications of present horticultural practices and greater use of greenhouse technologies are some of the solutions to mitigate the effects of climate change. Improvement of new cultivars of horticultural crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yields under stress conditions; as well as implementation of hi–tech horticulture and careful management of land use resources are going to be the main strategies to meet

Table 3. Plant population in one acre of coconut plantation (Source: Parulekar et al., 2020)

Name of crop	Variety	Number of plants
Coconut	DXT	70
Nutmeg	Konkan Swad	54
Cinnamon	Konkan Tej	246
Black pepper	Panniyur -1	140

Table 4. Average yield of coconut per palm and before and after planting spice crops and percent increase in different blocks of spice crops (1982-2003) (Source: Anonymous, 2015)

Block	Cinnamon	Nutmeg	Black pepper	All spice	Clove	Garcinia	Control
Average yield before planting spices	69	71	83	49	47	64	77
Average yield after planting spices	118	119	102	93	92	96	Average yield of 26 years
Per cent increase	71	69	23	90	96	50	

the challenges of productivity losses.

There is an urgent need for: i) conservation, management and documentation of resources in western region, and ii) promotion of protected cultivation of vegetables and flowers and horticultural species including forested trees in the coastal Konkan and part of the Western Ghats keeping in view the impending climate change and its mitigation and coping with the climate-change-induced disasters.

The SAUs and ICAR institutes need to be involved for i) detailed study on impact of climate change on horticultural production and productivity and suggest adaptation and mitigation strategies; ii) the climate-resilient varieties (for example Vengurla-4 for cashewnut, Pratap for coconut; Ratna and Kesar varieties for mango) (**Figure 16**); iii) assessing organic carbon status in coastal soils using different models

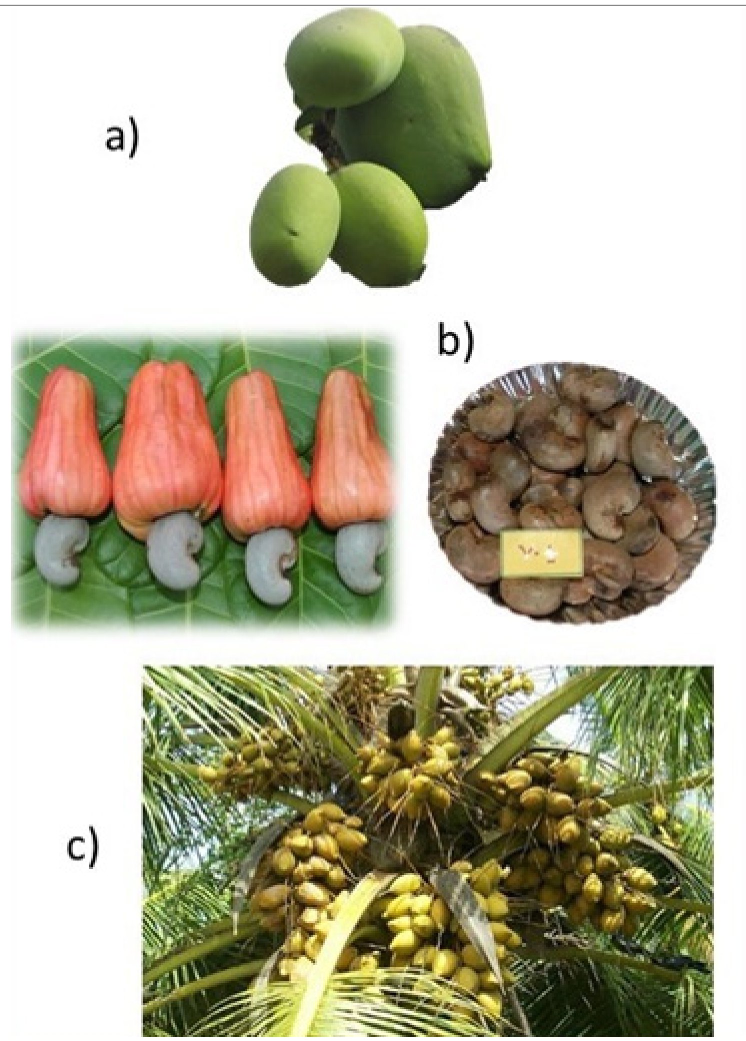

Figure 16. a) Alphonso hybrid variety Samrat (cross between Alphonso and Tommy Atkins) can withstand climatic vagaries; b) climate-resilient cashew nut variety Vengurla-4, and c) Pratap: climate resilient variety of coconut

Figure 17. Tuber crops (a); and the potential area to offset impact of climate change in Konkan, Maharashtra (b)

to comprehend that only surface soil data do not suffice and justify soil carbon and crop models. Subsurface databases are necessary (Bhattacharyya et al., 2007a, b). Some of these findings have a bearing on horticulture in Konkan (Bhattacharyya et al., 2019b); and iv) conserving soils through proper planning since effect of warming on SOC loss is buffered by increased soil depth (which effect of warming) may be further reduced by the application of organics. Subsurface soils could be comfortable zone for crops to withstand warmng effect. Therefore, crops which are grown underground are useful to mitigate the effects of global warming. A host of tuber crops might also offset impact of climate change (**Figure 17**).

Appropriate steps and forewarning to counter the adverse impacts of heavy rain, flooding, cyclonic disaster to protect crops and trees and plantations and providing a window for insurance against such calamities involving research and educational institutes are a must.

With 2015-16 as the base year, DBSKKV, Dapoli has taken number of initiatives for 'doubling farm income' (DFI) in all the horticultural farms/orchards to showcase the achievability of the national DFI targets. These initiatives are underway at various research stations located in different parts of Konkan and are expected to serve as the useful models to achieve the national DFI goals (Bhattacharyya et al, 2018c).

Diversification through area expansion by commercialization of other major fruit crops like jackfruit, jamun, breadfruit, karonda, kokum, tuber crops and native flower crops is required. Diversification of coastal horticulture needs to be dove-tailed with the integrated farming system approach for better use of natural resources. All the SAUs and ICAR institutes should be in the network for weather-based agro-advisories to reduce risks of climate vagaries; focus on reviving horticulture after disasters, if it happens. Networking with wide range of government, CGIAR, and civil society organisations is needed for harvesting synergy through convergence to make horticulture and the orchard owners a profitable venture amidst the threat of warming in this fragile coastal ecology.

Other steps which need attention include: i) horti-tourism promotional activities; ii) processing of various products for value addition; iii) high density planting and crop canopy management; iv) organic production of major horticulture crops including biological control of diseases and pests; v) strengthening of collective farming among small farmers; vi) establishment of R&D units for commercialization of health drinks, semi-moist products, fermented products like vinegar and wines, commercial industrial products like, pectin, papain, 2-hydroxy citric acid and standardization of waste utilization mainly cashew apple and cashew nut shell as huge waste during processing; and vii) establishment of self-employment training units with respect to post-harvest handling.

Way Forward

Climate change studies require huge datasets for the past and present scenarios to build the predicted incidences. There is a huge data gap with special reference to the natural resources. The data are available but in a scattered form and in many cases these are simply not accessible. So far as horticulture is concerned, soil information system for horticulture is in place (Bhattacharyya et al., 2019a). Primary data generation on demand, and filtering secondary data for modeling through systematic observations might help in accessing multiple regional climate models with higher resolution. This will involve inter-and trans-disciplinary research experts involving regional planners and advisors in a decentralized manner.

Non-governmental organisations may be preferred for such activities to avoid enterference. It is worth mentioning that many areas could be less affected by warming. For making contingent plans those areas should not lose sight of the experts.

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