Short Scientific Report *Journal of Plantation Crops, 2008, 36 (3): 372-374*

A temperature sensitivity analysis on plantation crops : A GIS approach

Keywords: Coconut, DIVA-GIS, pepper, site suitability, temperature variation

Climate change is an important event that has great potential impact on agriculture. The change in the climatic parameters would ultimately lead to the shift in the areas of cultivation because most of the areas where the crops are being cultivated may become unsuitable and some new areas may become suitable for cultivation. The implication is not as simple as it sounds. The suitability of the crops when eroded, would lead to the depletion of the native flora. For example, black pepper and coconut are predominantly cultivated in peninsular India and *Peper* is native to Western Ghats. A change in the climate leading to the unsuitability of the conditions for the growth and reproduction of the native crops would ultimately lead to the extinction of many native races and species. The ultimate result of genetic erosion would be too difficult to assimilate in view of crop improvement and ecology. The present study is an attempt to forecast the change in the suitability of plantation crops when the temperature is increased by 2ºC. For the study, two crops chosen are black pepper (*Piper nigrum*) and coconut (*Cocos nucifera* L.).

Black pepper grows from sea level to 1500 m MSL. It is a plant of humid tropics, required yearly uniform distributed rainfall of 2000 mm to 3000 mm. The crop tolerates temperature between 10º C to 40º C, but ideal temperature is 28º C.

In case of coconut which is also a tropical crop, grows from sea levels to an elevation of 900 m MSL. Yearly rainfall requirement ranges from 1000 mm to 2250 mm evenly distributed throughout the year. Optimum temperature ranges from 27º C to 32º C but it can stand in a range of 10º C to 35º C. It grows essentially in humid tropics.

Use of geographic information system (GIS) to assess land suitability of pepper and coconut for current and potential regions in Indian climate is the primary focus of the study. The assessment is based on spatial frequency distributions of measurable environmental criteria derived from characteristics of climatic requirement of the crop.

Crop growth simulation models are research tools usually applied in assessing the relationship between crop productivity and environmental factors. They have been shown to be efficient in determining the response of crop plants to changes in weather and climate. Examples of such models include EPIC (Williams *et al*., 1989), CERES (Ritchie, 1989) and GAPS (Butler and Riha, 1989). In most of the cases these crop models have been developed in particular localities and they are not always applicable in other regions without validation. Therefore, when introducing such crop models into new regions, their applicability needs to be evaluated. The Eco-crop model of DIVA GIS is a universal model which can be used for the crops of any region by adjusting the required climatic parameters. DIVA-GIS implement Eco-crop model to predict the adaptation of a crop over geographic areas. (Hijmans *et al.,* 2005). According to FAO, Eco-crop model can be used to assist in the identification of candidate species for defined environments. Similar models have been used extensively to evaluate the potential impact of climate change on shifts in the production and growing regions of various crops (Easterling *et al.,* 1993; Rosenzweig *et al.,* 1995; Tubiello *et al.,* 2000; Tubiello *et al.,* 2002).

The latest state wise data of area and production of coconut and pepper were collected from the secondary sources, (the record of spices board and statistics departments). The land suitability maps were drawn with the help of Eco-crop model of DIVA GIS. In Eco-crop model, the growing period is defined in days as between Gmin and Gmax (expressed in days). 12 possible growing seasons are considered, starting at the first of each month. The length of the growing season is defined as the average of Gmin (270 for coconut, and 180 for pepper) and Gmax,(365 for coconut and 270 for pepper) expressed as number of months.

Values of the temperature and rainfall parameters used for determining the suitability of a growing season are provided in Table 1.

Table 1. Values of the parameters used in the eco crop model

Parameter	Description	Values	
		Coconut	Pepper
KTmp	Absolute temperature that will kill the plant	-1	10
Tmin	Minimum avg. temp. by which the plant will grow	14	10
TOPmn	Minimum avg. temp. by which the plant will grow optimally	22	22
TOPmx	Maximum avg. absolute temp. by which the plant will grow optimally	34	35
Tmax	Maximum avg. temp. by which the plant will cease to grow	38	40
Rmin	Minimum rainfall (mm) during the growing season	650	2000
Ropmin	Optimal minimum rainfall (mm) during the growing season	1200	2500
Ropmax	Optimal maximum rainfall (mm) during the growing season	2400	4000
Rmax	Maximum rainfall (mm) during the growing season	4000	5000

The suitability map (based on existing weather conditions) shows that Kerala, as a whole and Eastern coast of Tamilnadu Western parts of Karnataka and Maharastra are very suitable for coconut cultivation (Fig. 1a.). Whereas, West Bengal, Orissa, Parts of Andra Pradesh, Madhya Pradesh and Gujarat are suitable to very suitable, while Assam, Bihar and parts of Madhya Pradesh are marginally suitable. The suitability map when correlate with the latest area and production it shows that Kerala, Karnataka and Tamil Nadu which are having excellent suitability are having very high area under coconut cultivation. It is interesting to note that Assam shows marginal suitability and area under cultivation, but productivity level is very high, may be due to Assam tall variety which is having a very good yield.

The map prepared with increase of temperature by 2ºC (Fig. 1b) shows West Bengal, Orissa, Assam are becoming totally unsuitable for coconut cultivation. According to Naresh Kumar (2008) coconut productivity will increase 10% by 2020, 16% by 2050 and 36% by 2080, only due to climate change in the west coast. But it will be tempered by a decline of 2%, 8% and 31% respectively in the eastern coast. This study was made on the basis of climate change model. But the Eco-crop model which is prepared by altering temperature parameters also shows a decline in the eastern coast as West Bengal and Orissa are becoming unsuitable for coconut cultivation.

The Eco-crop model of suitability map (Fig. 2a) shows that eastern and northern part of Kerala is excellent to highly suitable for pepper cultivation (Kollam, Idukki, Wayanad, Calicut and Kannur). South eastern part of Karnataka is highly suitable while North eastern part is marginally suitable and in case of Tamil Nadu only a patch of south western part is highly suitable. Western part and a patch in eastern corner of Meghalaya shows, marginal to low suitability and the area under cultivation is restricted to those areas (the border of Bangladesh and Assam plains). Productivity of Meghalaya's pepper is very high. The collection records of Indian Institute of Spices Research shows that for almost all the collection site the altitude is round 1000m and optimum altitude for the pepper is between 100 and1000MSL. Though there are no reliable estimates of total area under cultivation of Pepper in Assam, Tripura, Mizoram and Arunachal Pradesh, the Eco-crop model shows these areas are very suitable for pepper

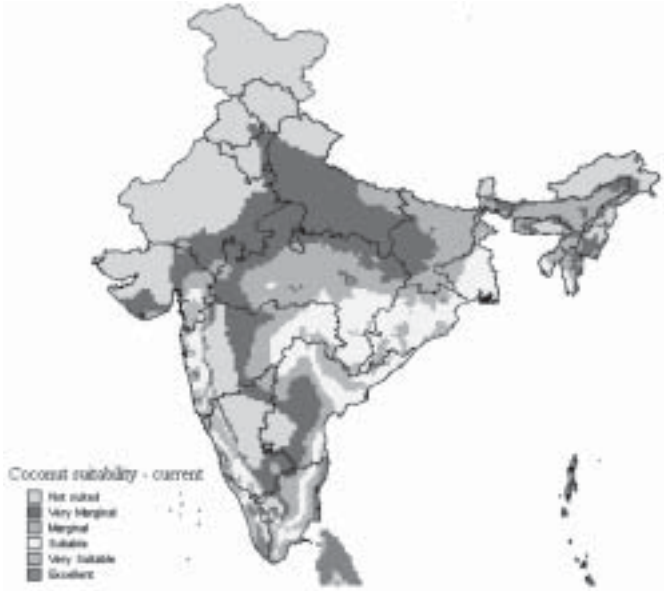

Fig. 1a. Eco-crop model for coconut suitability based on current values of parameters -(current)

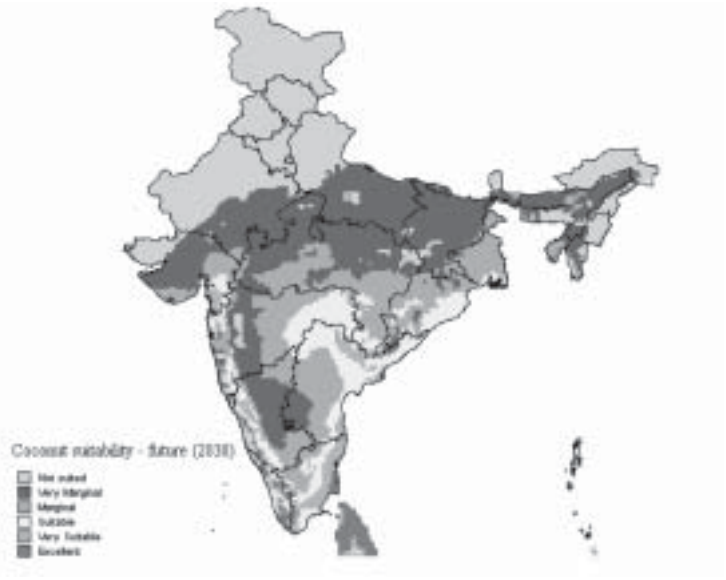

Fig. 1 b. Coconut Eco-crop model optained when the temperature increased by 2º C

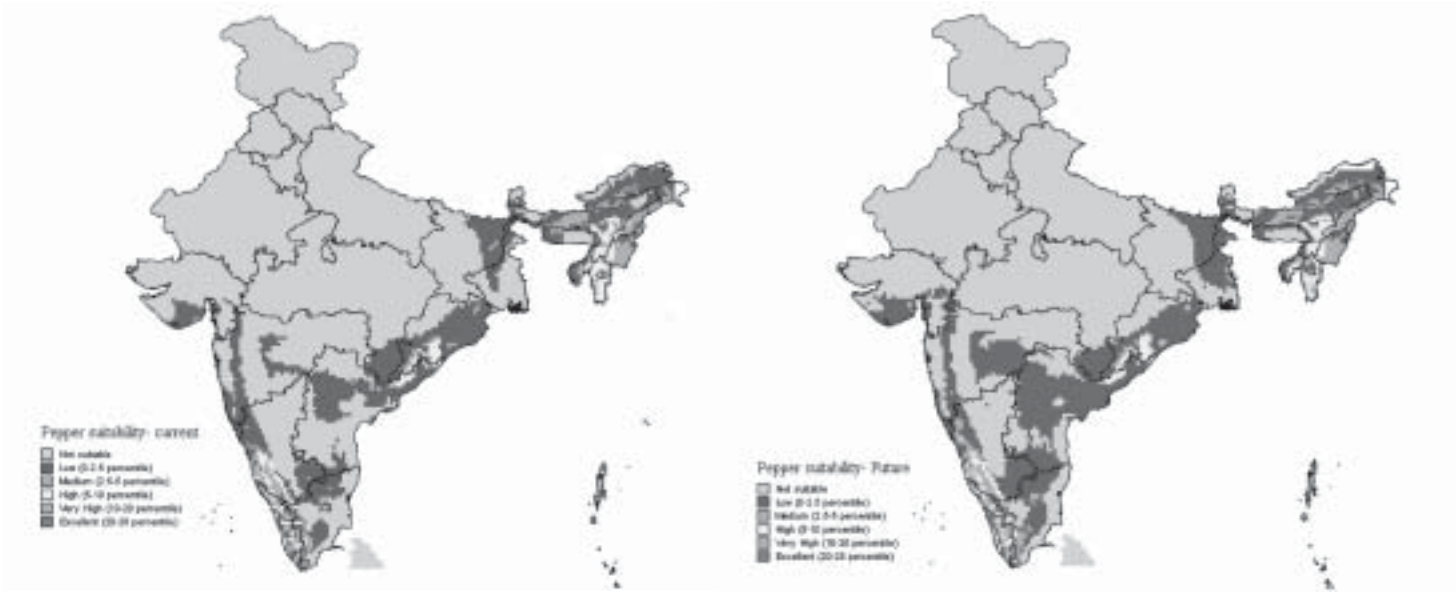

Fig. 2a. Eco-crop model for black pepper suitability : based on current values

Fig. 2 b. Pepper Eco-crop model : when temperature increase by 2º C

cultivation, Among the 110 *Piper* species reported so far from Indian origin; more than 90 species are found in the tropical evergreen forests and semi deciduous forests of North Eastern region. IISR collection records shows10 species from Mizoram and Arunachal Pradesh each. The Eco-crop model for the future prediction (Fig. 2b) shows that the suitability of Western Ghats will reduce while that of Eastern Himalaya's foot hills will turn to be more suitable.

Rainfall and temperature are the important climatic factors influencing the coconut yield (Peiris *et al*., 1995). The same is suitable for black pepper. But climatic variability increases across most climatic variables makes predictions uncertain. Changing risk of damaging events (heat waves, frost, droughts floods) which effect crops and timing of farm operations. Indian is home to Black pepper and has originated in Western Ghats. This regions has rich diversity which would run into depletion.

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