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RESEARCH ARTICLE

Influence of micro-climatic factors on biodiversity of cocoa (*Theobroma cacao* L.) plantations in Tamil Nadu

■ **N.S. VIGNESH, M. MAHESWARI AND P. DORAISAMY**

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SUMMARY : In India, cocoa is a viable intercrop in coconut, arecanut and oil palm plantations. Presently, the area under cocoa cultivation is expanding and this necessitates systematic investigations to assess the influence of cocoa plantations on micro-climatic factor and biodiversity. In this context automated micro-climatic analyzers with sensors were installed in both cocoa intercropped with coconut and coconut monoculture plantations in the farmer's field for continuous monitoring of weather parameters to assess the impact of cocoa cultivation as an intercrop on micro-climatic factors. The observations from automated micro-climatic analyzers with sensors showed a decrease in the air temperature under cocoa intercropped with coconut to a extent of 0.11^0 C to 0.34^0 C and a reduction in the soil temperature to a tune of 0.03^0 C to 0.7^0 C. The wind velocity was reduced drastically as the cocoa trees act as the wind barriers. The average solar radiation was reduced by 68.8 per cent under cocoa canopy. The soil moisture was high in the cocoa cultivated soil by 19 per cent as the cocoa litter fall acts as a mulching agent. The relative humidity was also altered by the cocoa cultivation. An increase in the faunal population by 34 to 42 per cent was recorded with the introduction of cocoa as an intercrop with the coconut. Drastic increase in the insect diversity, intensity and distribution were observed, as the shade and humid condition encouraged the insect diversity. The bird species diversity was not much altered but there was an increase in population as the cocoa has higher insect population. Overall field observations unequivocally demonstrated the positive impact of cocoa as an intercrop with coconut plantations in improving the biodiversity. Cocoa alters the micro-climatic factors which it turns provides a favourable condition to improve the biological health.

Key Words :
Cocoa plantations, Micro-climatic factors, Biodiversity, Cocoa

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Author for correspondence :
N.S. VIGNESH
Department of Environmental Sciences, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA
Email: vigneshns2009@gmail.com

See end of the article for **Coopted authors'**

Cocoa plays a very important economic role for small farmers. As a cash crop it can provides necessary income for the purchasing of food and is especially important in areas where food security has been a problem. The cocoa industries have enormous significance both for livelihoods in the developing world and for biodiversity. It is one of the world's most important agricultural export commodities, and as such, another vital source of foreign exchange. Livelihoods of millions of households depend directly upon the international cocoa markets.

Agro-plantation industry, through its monoculture is causing major erosion of biodiversity in many agricultural areas. Habitat transformations like urbanization and plantations lead to loss or alternation of biodiversity and micro-climatic factors, there is a need to scientifically manage the same. Reconciling development with conservation of biological diversity is the need of the day. Agro-plantations have over the years rapidly expanded in India, with large tracks of land being converted into monoculture areas. The ensuing biodiversity aspects have received very little attention from the scientific community. There is urgent need to undertake such biodiversity studies in major monoculture plantations in India. This is even more important in states like Tamil Nadu, as large scale plantations of coconut, tea, coffee and rubber occupy large tracks of land near the Western Ghats, which is a biodiversity hot-spot.

In India, cocoa is usually planted under coconut and arecanut plantations as it has an imminent capacity to share the alley spaces of tall growing coconut and arecanut palms and its combining ability with the micro-climatic conditions available in such perennial gardens. The cocoa tree flourishes in the dense shade of warm rain forests in its natural habitat and hence, can be cultivated in all similar climatic conditions. The cocoa cultivated as mixed/intercrop influence the micro-climatic factors and biodiversity in the agro-ecosystem.

EXPERIMENTAL METHODOLOGY

Micro-climatic analyzers with sensors were installed in the farmer's field for continuous monitoring of weather parameters to assess the impact of cocoa cultivation on micro-climatic factors. They were installed in coconut monoculture and cocoa intercropped coconut plantations which were 500 meters apart from each others. Micro-climatic analyzer has the sensors for measuring air temperature, soil temperatures at different depths, relative humidity, average solar radiation, soil moisture and rainfall and the data were recorded once in an hour in a data logger and retrieved for further analyses.

The faunal diversity was estimated by following the methods like net sweeps, light trap, pit-fall traps, scented traps and sticky trap based on the nature and habitude of the different species of insects and trapped insects were washed and preserved in 70 per cent alcohol. The faunal diversity was estimated by standardized quadrate method. The densities of grasses, sedges and broad leaved weeds and the total weeds were recorded at different cocoa fields and expressed as numbers per square meter. The avian diversity was estimated by fixed transect method and the samples were collected once in two months from cocoa intercropping area and coconut monoculture areas. Biodiversity Professional Version-2 software was used for the calculation of biodiversity parameters. Various biodiversity indices like Shannon and Simpson indices, cluster analysis and analysis of similarity were calculated by using the above mentioned software.

EXPERIMENTAL FINDINGS AND DISCUSSION

The results from the micro-climatic analyzers with sensors installed at western zone of Tamil Nadu showed a significant change in the micro-climatic factors due to introduction of cocoa under coconut plantations. It showed a decrease in the air temperature under cocoa intercropped with coconut to an extent of 0.11^0 C to 0.99^0 C and an increase in the relative humidity by 3.10 per cent over coconut monoculture. Soil moisture was higher in the cocoa intercropped coconut to a tune of 18.26 per cent over coconut monoculture plantation.The wind velocity was reduced drastically up to 81.44 per cent under cocoa intercropped plantation as the cocoa canopy acts as a wind barrier. The average solar radiation was reduced by 54.93 per cent and soil temperature was reduced by 0.48^0C to 2.49^0 C under cocoa intercropped plantations (Fig. 1). The canopy spread of the cocoa plantation lead to all the above changes in the micro-climatic factors, whereas the relative humidity was indirectly correlated with wind velocity and humidity increase will lead to reduction in the air temperature. The reduction in the average solar radiation resulted in the reduction of soil temperature and increase in the soil moisture level. Greenberg *et al.* (2000) referred that the cocoa forestry systems maintain many of the ecosystem functions and processes found in a like in primary forests. This includes low ground level light intensities, low transpiration rates of under storey plants, reduced wind speed and diurnal temperature and humidity fluctuations; large and continuous organic matter inputs; efficient nutrient cycling and diverse habitat for forest flora and fauna.

The change in the micro-climatic factors by introduction of cocoa under coconut monoculture resulted in the alteration of faunal, floral and avian diversity of the ecosystem. There is an average addition of three species of fauna which were observed only in cocoa intercropped area. The Shannon (H') Diversity indices was higher for cocoa intercropped area with respect to ages of cocoa and they were 1.146, 1.000, 1.135 and 1.106 in two, four, six, eight and ten year old cocoa plantations, respectively while the corresponding values for coconut monoculture were lower. Simpson (1/D) Diversity indices also showed higher values in cocoa inter cropped coconut (6.897, 4.335, 6.883 and 5.86, respectively) comparing to coconut monoculture (3.426, 2.948, 2.544 and 3.315, respectively) (Table 1). The difference in the faunal diversity under different ages of cocoa

Table1: Influence of cocoa cultivation on fauna diversity at western zone, Tamil Nadu

	Coconut monoculture*				Cocoa intercropped with coconut			
Particulars	2years	4years	6years	10years	2years	4years	6years	10years
Mean individuals	6.60	5.40	4.40	7.53	19.73	16.26	13.13	19.46
Standard deviation	12.75	11.46	10.21	14.83	22.54	26.66	15.16	25.50
Standard error	3.29	2.96	2.63	3.8	5.82	6.88	3.91	6.58
Total species	10	8	6	10	13	10	13	13
Shannon index	1.041	0.954	0.778	1.054	1.146	1.000	1.135	1.106
Simpsons index	3.426	2.948	2.544	3.315	6.897	4.335	6.883	5.86

* Age of coconut monoculture corresponded to cocoa intercropped plantations

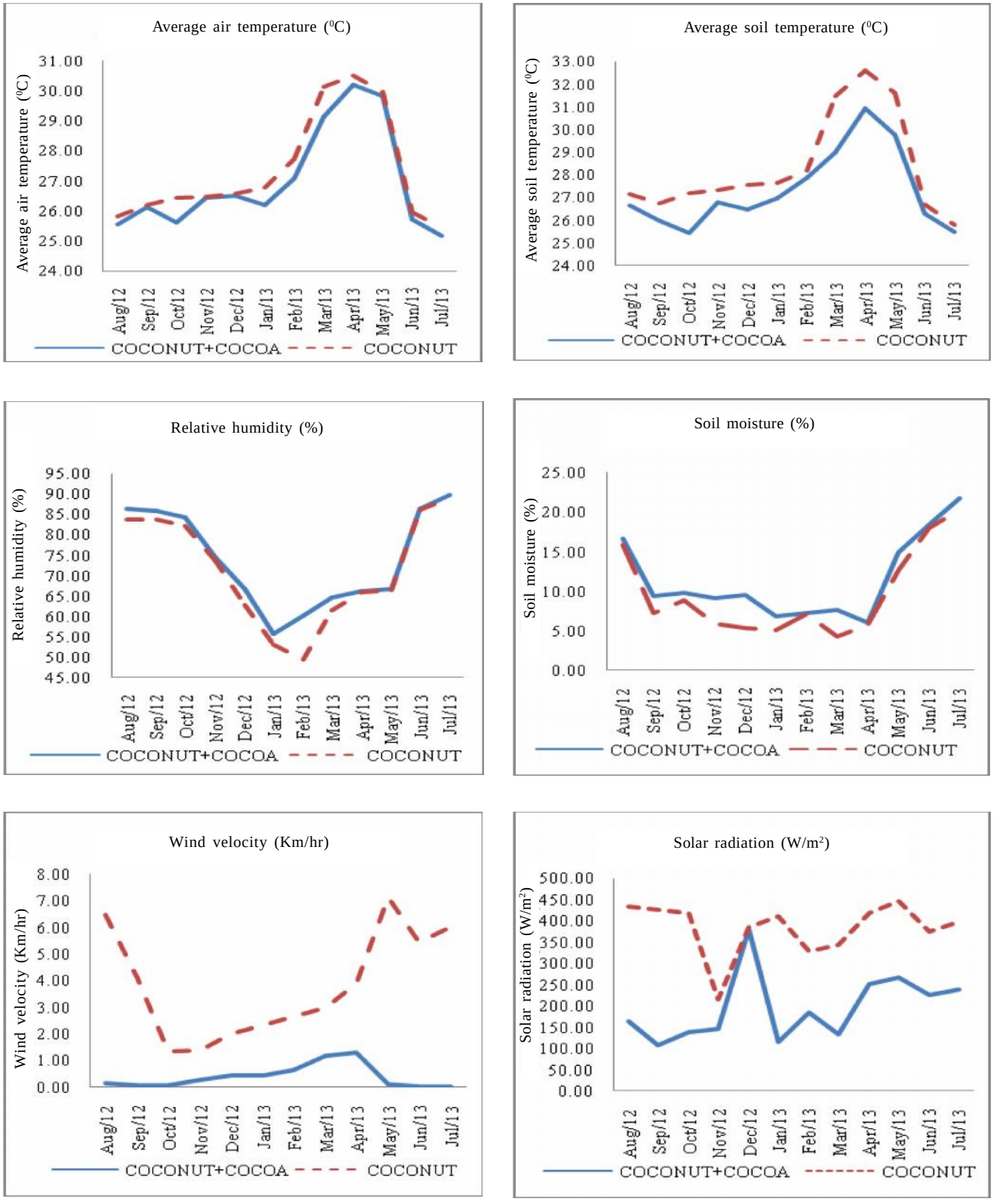

Fig. 1 : Influence of cocoa cultivation on microclimatic factors

cultivation was correlated by the canopy spread and the litter fall pattern and the age of the cocoa. The result was supported by the findings of Bawa *et al.* (2011) who explained that the cocoa cultivation will lead to addition of litter on the soil surface and alteration of soil temperature and relative humidity which will enhance the insect population as in the natural primary forest. The litter fall acts as a breeding ground for the insects and provides a favourable condition for the rapid growth and multiplication, perhaps there was a great increase in the insect diversity and population.

There was no. variation in the species but the numbers were drastically reduced to a tune of 53.4 per cent. The statistical analysis of Shannon (H') Diversity indices was lower for cocoa intercropped area irrespective of the age of cocoa and the values for coconut monoculture were higher recording 1.041, 1.079, 1.168 and 1.146, respectively. Simpson Diversity indices also showed higher indices in coconut monoculture (10.495, 11.191, 9.598 and 11.311, respectively) comparing to cocoa intercropped coconut (7.789, 8.107, 9.884 and 11.458 for 2,4, 6 and 10 years old, respectively) which was lower in the indices and represent the minimum floral diversity. The mean number of individual per observation was also 46.53 per cent lower in the cocoa inter cropped coconut compared to coconut monoculture (Table 2). The decrease in floral species distribution, abundance and infestation in cocoa plantations might be due to negative effects of competition for light, water and nutrients, as well as a potential effect of microclimate. These observations corroborate with the findings of Bazzaz (1996) and Chikoye and Ekeleme (2001).

The study on influence of cocoa plantations on avian diversity in cocoa plantations in comparison with coconut monoculture plantations at western zone of Tamil Nadu showed

Table 2 : Influence of cocoa cultivation on floral diversity at western zone, Tamil Nadu

Particulars	Coconut monoculture*				Cocoa intercropped with coconut			
	2years	4years	6years	10years	2years	4years	6years	10years
Mean individuals	41.80	54.73	31.40	71.80	27.40	31.53	16.33	17.66
Standard deviation	29.05	33.85	24.99	43.26	27.75	30.58	12.79	10.98
Standard error	7.50	8.74	6.45	11.17	7.16	7.89	3.30	2.83
Total species	13	15	13	15	11	12	11	14
Shannon index	1.041	1.079	1.168	1.146	0.994	1.006	1.019	1.134
Simpsons index	10.495	11.191	9.598	11.311	7.789	8.107	9.884	11.458

* Age of coconut monoculture corresponded to cocoa intercropped plantations

Table 3: Foraging based classification of avian diversity at western zone, Tamil Nadu

Sr. No.	Foraging type	CC Number of species	CC Number of birds	CC Weightage (%)	CM Number of species	CM Number of Birds	CM Weightage (%)
1.	Carnivores	2	11	7.01	1	7	4.38
2.	Frugivores	3	31	19.75	1	9	5.63
3.	Granivores	0	0	0.00	0	0	0.00
4.	Insectivores	4	31	19.75	2	14	8.75
5.	Nectarivores	1	16	10.19	1	9	5.63
6.	Omnivores	3	40	25.48	3	60	37.50
7.	Piscivores	0	0	0.00	0	0	0.00
8.	Scavengers	2	28	17.83	2	61	38.13
	Total	15	157	100	10	160	100

Particulars	CC	CM
Mean individuals	4.026	4.103
Standard deviation	6.90	10.308
Avg. total individual/visit	52.33	53.33
Total no. of species	15	10
Shannon value (H')	1.062	0.843
Simpson (1/D)	10.723	5.611

CC: Cocoa intercrop with coconut plantations; CM: Coconut mono culture plantations

an addition of five species of birds in cocoa intercrop area, namely, Asian Koel, Cattle Egret, Common Flameback, Shikra and Thick Billed Flower pecker. Cocoa intercropped with coconut had higher species diversification (15) compared to coconut monoculture area (10). The birds were categorized based on their food habit. Omnivore and scavenger species together constituted 5 species in both cocoa intercropped and coconut monocultured areas and it accounted for 43.31 per cent and 75.63 per cent of total birds population, respectively. In the cocoa intercropped area carnivores, frugivores, insectivores and nectarivores constituted 7.01 per cent, 19.75 per cent, 19.75 per cent and 10.19 per cent, respectively, while in coconut monoculture 4.38 per cent, 5.63 per cent, 8.75 per cent and 5.63 per cent, respectively. There was no piscivores and granivores category observed in the study area (Table 3).

Diversity indices of Shannon (H') and Simpson (1/D) were higher for cocoa intercropped area which recorded 1.062 and 10.723, respectively while the corresponding values for coconut monoculture were lower (0.843 and 5.611, respectively). This is discernible from the fact that cocoa agro garden facilitate the birds by simulating the climate and environment conditions which are akin to secondary forests. Tall variety of coconut along with twelve year old cocoa trees provided excellent shade, and this micro-climatic habitat was well utilized by the bird communities, which resulted in highest bird population.

In the present study with respect to foraging category, there is an increase in insectivores bird species to a tune of 45.20 per cent over monoculture area in the same region. This may be due to increased presence of insects on account of high litter fall from the cocoa and improved environmental factors like, decreased temperature; increased shade etc. This view is further re-enforced by Martius *et al.* (2004) who observed an increased insect population under shaded cocoa canopy. Present investigation revealed addition of five species of birds under cocoa plantation which were not present in coconut monoculture which may be due to habitual adaptation of birds towards introduced cocoa plantation and these results are in coordination with Botero and Baker (2001), who noticed such increase in bird species in correlate with diversified cropping system.

Conclusion:

There was a significant change in the micro-climatic factors due to the introduction of cocoa under coconut plantations. These results are in favour of conserving and improving the biodiversity. By growing cocoa as intercrop with coconut, there is an alteration in local climatic factors which has a positive influence on the soil fertility and productivity of cocoa. Due to the enhancement in canopy area, and improvement in habitat, the biodiversity in the cocoa grown areas are significantly improved.

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Co-opted Authors' :

M. MAHESWARI AND P. DORAISAMY, Department of Environmental Sciences, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA
Email: maheswarisekar2004@yahoo.com, dhurai54@gmail.com

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