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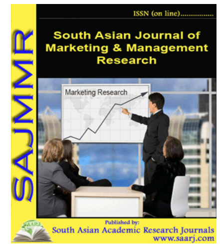

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MULTIPLE ECOLOGICAL SERVICES IN COFFEE AGRO ECOSYSTEMS ARE AFFECTED BY SHADE, ALTITUDE, AND MANAGEMENT

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ABSTRACT

Agro forestry systems contribute to farmer livelihoods and natural resource conservation by providing a variety of ecosystem services. Despite these well-known advantages, little is known about how shade trees influence the simultaneous supply of various ecosystem services, as well as possible trade-offs or synergies between them. To close this knowledge gap, we measured four major ecosystem services (pest and disease control, provisioning of agro forestry products, soil fertility maintenance, and carbon sequestration) in 69 coffee agroecosystems belonging to smallholder farmers in the Turrialba region of Cos. We next looked at bivariate connections between various ecosystem services, as well as specific ecosystem services and plant biodiversity, to see if there were any possible trade-offs or synergies. We also looked at which kinds of shade offered the best ecological benefits. The efficiency with which various kinds of shade provided ecological services was determined by how they interacted with altitude and coffee management, with different ecosystem services reacting differently to these variables. There were no trade-offs between the various ecosystem services examined or between ecosystem services and biodiversity, implying that several ecosystem services may be increased at the same time. Overall, low- and high-diversity coffee agro forestry systems were more capable of providing ecosystem services than full-sun coffee monocultures. According to our results, coffee *agroforestry systems should be planned with varied, productive shade canopies and maintained with a medium intensity of cropping techniques to ensure the ongoing supply of various ecosystem services.*

KEYWORDS: *Agro Forestry, Carbon Sequestration, Coffee, Soil Fertility, Yields.*

1. INTRODUCTION

Despite the fact that agro forestry systems have the ability to offer a wide range of ecosystem services, little is known about how shade trees influence the supply of various ecosystem services and the possible trade-offs or synergies between them. Most agro forestry research has concentrated on a single ecosystem service, rather than looking at connections between several ecosystem services. Furthermore, most research has only looked at the individual impact of shade on ecosystem services, ignoring other variables like as management methods and environmental circumstances that may interact with shade to produce ecosystem services. To design high-performing agro forestry systems, however, a thorough knowledge of the many variables influencing the supply of ecosystem services, as well as their interconnections, is required, as is a study of linkages (trade-offs or synergies) among ecosystem services Understanding how agro forestry systems provide ecosystem services is especially essential for the coffee industry in Central America, which is presently under tremendous stress. Since 2012, a series of factors has resulted in a substantial reduction in coffee output, including lower coffee prices, higher production costs, and an epidemic of coffee leaf rust[1].

Farmers were obliged to stump their affected coffee estates after the coffee rust epidemic in order to rejuvenate coffee trees, replenish them with new coffee types, or even replace them with other crops . The loss of shade trees and other vegetation caused by the conversion of coffee plantations to other land uses has a detrimental impact on plant biodiversity. Information on the potential advantages given by shade trees linked with coffee plantations may motivate decision makers, technicians, and farmers to preserve and/or expand land uses under coffee agroforestry systems, thus halting their decline The goals of this paper were to evaluate the effectiveness [2] .

We identified important elements that should be addressed for the design and management of coffee agroecosystems to guarantee the ongoing supply of various ecosystem services based on our results.In the canton of Turrialba, Costa Rica, a coffee plot network (69 plots) was created. Turrialba lies in a premontane wet forest living zone, with an average annual rainfall of 2781 mm and a mean annual temperature of 22.2°C (averages for the past ten years), with minor monthly fluctuations. Coffee is produced between 600 and 1400 meters above sea level in this region .When compared to farms at lower altitudes, farms at higher elevations have somewhat wetter and colder weather. The goal of the plot sample method was to pick coffee plots with various shades of shad across altitudinal and management intensity gradients. Plots were chosen based on differences in botanical composition and structure of shade canopies, as well as differences in coffee cropping practices and altitude. However, we selected coffee plots that shared three key features in order to minimize variability and prevent confounding effects of various variables. They were owned by smallholder farmers, had coffee plants of the dwarf variety Caturra as the sole or dominant variety, which is the most common variety in Costa Rica and other Central and South American countries were grown on Inceptions, suborder Udepts soils [3] .

A circular area of 1000 m2 was constructed in the middle of the experimental subplot to evaluate shadow canopy characteristics (17.8 m radius).A GPS was used to determine the height of each coffee plot. All coffee plots had a mean altitude standard deviation of 877 126, ranging from 646 to 1107 [4] .

The Management Intensity Index (MII) is a metric that measures howSemistructured interviews with farmers were used to collect data on management. For each coffee plot, a management intensity index was generated. Existing management intensity indicators used in coffee research were utilized to make the computations. First, the number of times per year that each cropping technique was used was converted to a value IH or IL between 0 and 1 indicating the intensity of the practice; the greater the value, the higher the intensity: where IH is the transformed value for cropping practices where a lower value denotes a higher management intensity (e.g. number of weedings, fertilizer application, fungicide application, etc. and IL is the transformed value for cropping practices where a lower value denotes a higher management intensity (e.g. distances between coffee rows and between coffee plants); value was the arithmetic mean of the arithmetic mean of the arithmetic mean of The management intensity index of each coffee plot was then calculated by adding the converted data for all cropping techniques (highest achievable = 11, since we had 11 cropping practices)[5] .

Musaceae (bananas and plantains), service trees (i.e., nitrogen-fixing plants), fruit trees, and timber trees were all categorized. The diameters of the trunks and Musaceae stems were measured at 1.3 m from the ground (breast height); the diameters of the fruit trees were measured at 0.30 m. The height of the main stem was also measured for service trees like Erythrina poeppigiana, which are pollarded once or twice a year. The trunk diameters of the eight indicated coffee plants were also measured at 0.15 m above ground level. Shade cover (percent) was measured at the four corners and in the center of the experimental subplot using a spherical densiometer, and then averaged.

2. DISCUSSION

2.1.Application:

The impacts of altitude, management intensity (quantitative data for both variables), kind of shade (qualitative data), and their interactions on each particular ecosystem service indicator were estimated using a linear model. The normalcy of ecosystem service indicators was first determined. The model selection process was then repeated multiple times for each indicator. Non-significant variables or interactions were eliminated from the model each time. The factors that were kept in the final model were those that were thought to have an impact on the ecosystem service indicator in question. The impacts of different kinds of shade on ecosystem service indicators were further compared using analysis of variance and Fisher's LSD test (p 0.05). The impacts of significant double and triple interactions among the variables on ecosystem service indicators were graphically depicted.

The researchers used bivariate linear regressions to compare indicators of the four ecosystem services examined, as well as indicators of ecosystem services and plant biodiversity. Trade-offs is indicated by strong negative connections, while synergies are shown by large positive ones. In the bivariate linear regressions, just one indicator that best reflects each ecosystem service was chosen for simplicity and to emphasize only the most significant connections between ecological service indicators. Because it is regarded as a broad indication of plant sickness, the number of dead branches was selected as a representation of pest and disease service regulation. Coffee yield was chosen as the indicator of provisioning services because it is of interest to both smallholder farmers (who are looking for ways to diversify their incomes but still rely on coffee as their main source of income) and medium and large farmers (who have coffee as their only product of interest). Because soil acidity is a common issue in tropical regions, and treating acidity requires significant additional costs (time and inputs) for farmers, soil acidity was selected as a representation of the maintenance of soil fertility service. Carbon sequestration was calculated using total aboveground biomass carbon. Finally, as a measure of biodiversity, the Shannon index of plant diversity was employed. Regressions were run on all of the data as a whole, as well as per kind of shade, to see whether ecosystem services are linked to a specific type of shadow. This method and analysis has been shown to be helpful in evaluating and designing agro ecosystems [6].

2.2.Advantage:

Shade, altitude, and management showed varying impacts on pest and disease control across various pests and illnesses. Regardless of the shade type, both altitude and management intensity had substantial single beneficial impacts on leaf miner insect and brown eye spot attack levels, with attack levels rising with higher altitudes and management intensities .The frequency of Anthracnose, on the other hand, was unaffected by altitude, treatment, or shade. The most important disease, coffee leaf rust, was substantially influenced by the double interaction altitude type of shade, but not by management intensity in any way. The soup of coffee leaf rust reduced with increasing altitude (indicating more rainfall and lower temperatures) in CFS and CHD, but not in CLD. These findings indicate that under various kinds of shade, coffee leaf rust reacted more to environmental circumstances than to management intensities surprisingly, the disease responded similarly in the two most dissimilar settings.

For dead branches, the triple interaction of altitude, type of shade, and management intensity was significant: the number of dead branches was lower at higher altitudes and increased with increasing management intensity in CFS only, while remaining practically constant in CLD and slightly decreasing in CHD. Management intensity had only a favorable impact on coffee production. The level of management intensity has a substantial beneficial impact on cash flow and family benefits however; the kind of shade management had a substantial double interaction impact on cash expenses and a large triple interaction effect on gross revenue. Increasing management intensity raised CFS and CHD cash costs significantly, but had no impact on CLD cash costs .Gross revenue was consistently higher in coffee plots with higher management intensity although it rose in CFS and dropped in CLD as altitude climbed. These findings indicate that, regardless of plot altitude, the costs of raising management intensity (and therefore boosting coffee production, cash flow, and family benefits) were clearly greater in monocultures than in agro forestry systems [7].

2.3.Working:

The indicators of each kind of ecosystem service reacted differentially to the impacts of height, shade, and management in our research. Furthermore, no obvious trade-offs existed between various ecosystem services or between ecosystem services and biodiversity. The fact that the triple interaction altitude type of shade management intensity affected at least one indicator of three major ecosystem services indicates that the combination of these three factors should always be considered in studies aimed at understanding the provision of ecosystem services by the cropping systems under study.

Understanding how to manage coffee agroecosystems to achieve the ecosystem services of interest requires combining knowledge of single and/or interaction effects of shadow with altitude and management intensity on ecosystem services. For example, the most significant disease in our research, coffee leaf rust, was influenced by the interaction types of shadow and altitude, but not by management intensity. As a result, attempts to control coffee leaf rust should take into account both the kind of shade and the altitude, which affects environmental and microclimatic conditions. In higher altitudes, highly varied coffee systems will be more effective in reducing coffee leaf rust occurrences, while lower altitudes will benefit from less diversified agroforestry systems. We believe that the less diverse canopies maintain low moisture at lower altitudes, whereas the highly varied canopies maintain low temperature at higher elevations, reducing disease growth.

This implies that, in addition to delivering numerous ecosystem services, agroforestry systems did not decrease coffee yields within the investigated shadow cover range (30%). Furthermore, under shade, yields are more consistent throughout time, providing more consistent revenue for coffee producers. Coffee farms in full sun, on the other hand, had more dead branches, particularly when management intensities were high [8].

The Desired region is the quadrant in the image where both indicators have the most desirable values. For example, in the combination of carbon sequestration and plant biodiversity, the desirable area is the quadrant in the upper right corner of the figure, because plots in this quadrant had higher TAGB Carbon and higher Shannon index; in the combination of provision and regulation of P&D, the desirable area is the quadrant in the upper left corner of the figure, because plots in this quadrant had high TAGB Carbon and higher Shannon index; in the combination of provision and regulation of P&D, the desirable area is the quad The percentages(%) above each figure indicate the amount of coffee plots of a certain shade type in the desired region in relation to the total number of coffee plots of that shade type. In the graph of carbon sequestration vs. biodiversity, for example, 10 CHD coffee plots were found in the desired area, accounting for 34% of the total of 29 CHD coffee plots. For CHD plots, the only substantial connection (a synergy) between biodiversity and carbon sequestration was discovered. Years to come may be anticipated .The decrease of yields, or yield losses, is also seen as a crucial indication of pest and disease control; as a result, it should be clearly measured in future research to support the evaluation of this ecosystem function We discovered that agroforestry systems may be less expensive to operate than full-sun systems. This suggests that the management intensity of these agroforestry systems may be raised without necessarily incurring significant financial expenses.

The administration of the shade canopy would not add to the expenses. Cutting banana leaves, pruning trees, and harvesting fruits, for example, are usually done by family members in conjunction with operations performed on coffee plants (coffee plant pruning, weeding, harvesting, and so on); in this way, those activities do not necessitate the hiring of external workers or a large amount of extra labor. Contrary to expectations, there was no relationship between shade kinds and management and cash flow or family benefit. This reflects the fact that agroforestry goods (such as bananas, other fruits, and wood) are seldom harvested in Turrialba for sale or household consumption. Farmers in other areas with poorer socioeconomic circumstances value the contribution of agroforestry products higher. Guatemalan coffee growers, for example, gather fruits for sale, whereas Peruvian farmers utilize fruits for personal use.

The key aspect is that plants and trees found in coffee agroforestry systems may be picked whenever farmers need goods for consumption or sale, which is not feasible with coffee grown in direct sunlight. This is particularly essential during low-cost or low-production coffee crises in our research, coffee agro forestry systems produced more than twice as much aboveground carbon as coffee grown in direct sunlight. Coffee agro forestry systems in other areas of the globe may store much more carbon owing to their more varied and thick shade canopies. For example, aboveground biomass stocks in Guatemalan, Nicaraguan, and Mexican coffee agro forestry systems may exceed 40 Mg [9].

In full sun, agro forestry systems had higher soil fertility than coffee, whether the impacts of different kinds of shade were considered alone or in combination with management intensity. Shade is also important for soil fertility in coffee agro ecosystems, according to several researches. More trees equals less nitrogen loss Bananas may aid in action exchange capacity improvement .Shade was shown to be essential for lowering acidity and raising K independently of other variables in our research, and it was also capable of sustaining greater soil C and N levels as management intensity increased .

Shade trees and bananas may decrease the requirement for nitrogen fertilizers and additives to rectify soil acidity, lowering soil contamination as well as production costs. Furthermore, although soil physical indicators that are essential for soil fertility were not examined, it is well known that soil C is linked to organic matter and improved soil physical characteristics There were no trade-offs between ecosystem services or between particular ecosystem services and biodiversity, as far as we could tell [10].

Trade-offs between yields and carbon sequestration, yields and biodiversity and yields and disease control described in the scientific literature on agro forestry systems were anticipated, but did not occur. The absence of trade-offs among the ecosystem services examined is a new finding. This may be explained by the fact that ecosystem services are a result of the system's composition as well as its management i.e. the interplay between both variables. With proper management, highly diverse systems should be able to provide large amounts of ecosystem services without trade-offs. Provision of other tree products and carbon sequestration are all examples of how system management can have a significant impact on coffee pollination and production. Many distinct kinds of shade and cropping techniques may be found in Turrialba, each with a different response in terms of ecosystem service supply. There were no trade-offs across ecosystem services since some coffee plots had low values of an ecosystem service and other coffee plots of the same kind of shade had high values of the same ecosystem service. However, not all synergistic connections between ecosystem services are created equal [8].

3. CONCLUSION:

The ability of various kinds of shade to offer significant ecosystem services in coffee plantations is dependent on both the altitude at which the coffee is produced and the management of the system. There were no trade-offs between various ecosystem services or ecosystem services and biodiversity in our research. This suggests that increasing the supply of ecosystem services without reducing the provision of other ecosystem services is feasible. Coffee agro forestry systems offer more ecosystem benefits than full-sun coffee systems. To guarantee the ongoing supply of various ecosystem services, coffee agro forestry systems should be planned with varied, productive shade canopies and maintained with a medium intensity of cropping techniques. The substantial impacts of management intensity on indices of provisioning service revealed in this and other recent research indicate that both low and high management intensity may have a negative impact on provisioning service. Shade canopies with a wide range of species need special attention.

In places where disease outbreaks are common, such as coffee leaf rust, and when soil fertility is deemed average in believe that the greatest choice for smallholder growers is this is how we characterize this management includes two fungicide treatments against illnesses each year. At least one fertilizing of the soil, at least one trimming of the coffee plants Weed management are required, as are harvest labors based on the maturity of coffee fruits. Keeping a shadow cover of approximately 30% throughout the year Such Pest-resistant coffee varietals should also be included in the management plan. And illnesses don't do things that aren't essential to save money, utilize family labor and decrease input amounts.

Disservices should be avoided or minimized. Poisoning of family members, death of non-target species, soil pollution, and greenhouse gas emissions Instead of chemical pesticides, insects are used. When organic fertilizers are available, they should be used whenever feasible. Enhance the physical properties of the soil Extension and training of farmers in agriculture, as well as sufficient qualifications, market-based incentives, and remuneration may aid in the adoption of well-designed, long-term coffee agro forestry systems that offer both environmental and economic benefits. Benefits to both the economy and the environment Agro forestry is in short supply. Farmers may benefit from education and extension .be a part of trainings that use participatory methods.

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