



## ASSESSING THE LONG-TERM EFFECTS OF INTENSIVE MONOCULTURE ON SOIL MICROBIAL DIVERSITY AND NUTRIENT CYCLING IN SUBTROPICAL CROPPING SYSTEMS

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### Abstract

This study investigates the long-term ecological impacts of intensive monoculture farming in subtropical regions and evaluates the potential benefits of diversified agricultural practices. Through a mixed-methods approach, including soil nutrient analysis, microbial diversity profiling, and farmer perception surveys, we compared monoculture systems with diversified approaches such as intercropping, crop rotation, and cover cropping. Results revealed that monoculture practices significantly deteriorate soil quality, as indicated by reduced pH levels, lower organic carbon content, and diminished microbial diversity indices (Shannon and Simpson). Soil under diversified systems, in contrast, exhibited improved macronutrient levels (N, P, K), enriched microbial communities, and enhanced carbon sequestration. Farmer surveys confirmed greater concern regarding soil degradation and pest outbreaks under monoculture, with over 85% of monoculture farmers reporting ecological decline compared to only 25% in diversified systems. Yield trend analysis from 2020 to 2023 demonstrated a consistent decline in monoculture outputs, while diversified systems showed a progressive increase in productivity. Additionally, pest outbreaks were reported to be twice as frequent in monoculture fields. These findings substantiate the ecological superiority of diversification strategies, emphasizing their role in improving soil health, boosting resilience, and stabilizing yields. The study concludes that transitioning away from monoculture towards diversified agroecosystems is critical for long-term agricultural sustainability, and calls for policy interventions, farmer support programs, and education to facilitate this transformation in subtropical agriculture.

## INTRODUCTION

Greed for achieving increased food supply and better profitability have made it common for subtropical areas to practice raising single crop species over and over (Soares et al., 2023). These farming systems are useful because they allow large production and are simple to take care of, but their long-term ability to last is not certain because they may harm soil health, diversity among microbes, and the way nutrients are used in the ecosystem (Nwaogu & Cherubin, 2024). Using monoculture and a lot of herbicides that do not pick certain plants affects the variety of plants in different regions (Groot et al., 2020). Even though monoculture systems boost quick-term results, over time, they can disturb nature in the soil and influence both the general and soil health. To farm subtropically in an eco-friendly way, people need to be aware of these effects. Most farmers choose monoculture since this approach boosts their profits and crop yields (Suárez & Gwozdz, 2022). Still, studies in science point out the major role ecosystem services have in and around monocultures (Suárez & Gwozdz, 2022).

The disorder of soil microbes occurs if a single species is continued to be planted all the time (Zhang et al., 2023). Such a broadening may set off several soil functions like providing and moving nutrients, breaking down organic matter, and lowering the risk of diseases (Jat et al., 2021). A long-term application of monocultures tends to make the soil food web less complex, which lowers the number of interactions between different organism groups (Giacinto et al., 2020). Such a change in the soil ecosystem may make it harder for the agroecosystem to handle changes and outbreaks, such as pests and problems caused by climate change (Phogat et al., 2020). After the 1950s, monoculture farming has expanded in connection with increases in industry, more uniform agricultural products, easier transportation, and higher sales of both food and fiber (Akanmu et al., 2023). Since monocultures involve one kind of plant, they create less diverse habitats and it causes a decrease in the number of soil organisms.

Since there are only one kind of plant in a monoculture, the soil receives fewer types of organic substances, which limits how the microbial population works. With this being said, the soil microbiome might not function properly in important duties such as nutrient cycling and challenging organic compound decomposition. Monoculture farming has led to water pollution, erosion of the soil, and less diversity in living things (Dudek & Rosa, 2023). In addition, if the same crop is grown over and over again, it could bring about problems with diseases and pests in the soil, raising the chance of outbreaks and using more pesticides and herbicides. No rotation of crops in monoculture systems interrupts the cycle of nutrient supply and uptake, which results in poor use of fertilizers and sometimes imbalances of nutrients.

If diverse species are added to farmland, the problems of monoculture may be resolved. The different farming methods may cause lower production mainly because of issues such as limited access to markets, lacking processing, inadequate knowledge, and poor infrastructure.

Putting in cover crops, growing several crops at once, and rotating different crops are some ways to boost the soil's nutrition and microbial life. Such strategies change the soil's physical and chemical properties, promote absorption of water, and add extra carbon to it (Feyissa et al., 2021). The results are better when you use different diversification strategies instead of just personal management (Rasmussen et al., 2024). When water is absorbed better, carbon is held, and soil is stabilized with more types of crops, the general soil becomes stronger and

healthier. Even though the research on this topic is advancing, scientists are still studying the results of using more different crop types in agricultural systems (Beillouin et al., 2021).

When the same crop is grown every year, nutrients might become unbalanced and fertilizers will not be used efficiently. Using monocultures may result in more required synthetic fertilizer. This can end up altering the quality of water and the condition of soil. Farming the same crop on many acres means plants do not receive enough potassium, nitrogen, and phosphorus. Excessive nitrogen fertilizer use could result in rivers becoming excessively rich in nutrients, emissions of greenhouse gases, and decreasing soil's health. In addition, if the nutrients in the soil are deployed too often and not replaced sufficiently, the land might not be productive for a long period.

It might be necessary to make major changes to agricultural methods and equipment to support more diverse farming at wide areas (Goslee, 2020). Spreading farming activities across many regions may reduce the effects of climate problems, pest infestations, war, and worldwide pandemics on food production (Smith et al., 2023). Making more types of crops can improve food supply where you live, and since this would reduce the area needed for food, it would help the region's economy and develop more fair and sustainable local food systems. It is aligned with worldwide actions aimed at climate change and saving different life forms (Sethuraman et al., 2021). However, many challenges have been linked to both the access and the expenses of eating fruits and vegetables (Kapari et al., 2023).

Growing many types of the same crop species side by side helps deal with insect pests and offers benefits for both your budget and your health. Disease management practices include this method and can also support the built of different agroecosystems (Snyder et al., 2020).

## **METHODOLOGY**

The study applied a mixed-methods approach to collect information by gathering both sets of data. For each of two farming seasons, field studies were done in heavily monocultured areas to see how soil quality, the kinds of microorganisms, and crop nutrient balance were affected by yearly planting of the same crop. The content of major nutrients (N, P, K), the level of organic carbon, and the pH balance were next determined by collecting soil from the both types of farms and testing them in the laboratory. With 16S rRNA and ITS region DNA analysis, the diversity of microbes in the various treatment plots was investigated and the microbes were easily identified. Among the groups, those practicing monoculture as well as those practicing mixed or diversified farming all did semi-structured interviews and group discussions at the same time. The researchers tried to observe the ways farmers adapted as a result of lowering environmental quality, adjusted due to legal guidelines, and were affected by economic issues. Using Principal Component Analysis (PCA) and Non-metric Multidimensional Scaling (NMDS), the study assessed the community structure of microbes, while differences in soil health indicators between the monoculture and diversified plots were compared statistically by using ANOVA and multivariate regression analysis. A thematic analysis was applied to qualitative data to put forward essential subjects on institutional support, the way farmers view things, and the challenges with infrastructure. Combining information from ecological assessments and input from stakeholders allowed the study to give a full explanation of

monoculture effects and the chances behind diversification for saving the environment. It was confirmed by the institutional review board that human interaction could proceed after all participants consented to take part. Thanks to this approach, we gathered information from various sources and found out how to build farming systems that are both sustainable and friendly to species in subtropical areas.

## RESULTS

The study applied a mixed-methods approach to collect information by gathering both sets of data. For each of two farming seasons, field studies were done in heavily monocultured areas to see how soil quality, the kinds of microorganisms, and crop nutrient balance were affected by yearly planting of the same crop. The content of major nutrients (N, P, K), the level of organic carbon, and the pH balance were next determined by collecting soil from the both types of farms and testing them in the laboratory. With 16S rRNA and ITS region DNA analysis, the diversity of microbes in the various treatment plots was investigated and the microbes were easily identified. Among the groups, those practicing monoculture as well as those practicing mixed or diversified farming all did semi-structured interviews and group discussions at the same time. The researchers tried to observe the ways farmers adapted as a result of lowering environmental quality, adjusted due to legal guidelines, and were affected by economic issues. Using Principal Component Analysis (PCA) and Non-metric Multidimensional Scaling (NMDS), the study assessed the community structure of microbes, while differences in soil health indicators between the monoculture and diversified plots were compared statistically by using ANOVA and multivariate regression analysis. A thematic analysis was applied to qualitative data to put forward essential subjects on institutional support, the way farmers view things, and the challenges with infrastructure. Combining information from ecological assessments and input from stakeholders allowed the study to give a full explanation of monoculture effects and the chances behind diversification for saving the environment. It was confirmed by the institutional review board that human interaction could proceed after all participants consented to take part. Thanks to this approach, we gathered information from various sources and found out how to build farming systems that are both sustainable and friendly to species in subtropical areas.

**Table 1:** Soil pH under different cropping systems

| Cropping System | Soil pH (mean $\pm$ SD) |
|-----------------|-------------------------|
| Monoculture     | 5.2 $\pm$ 0.3           |
| Intercropping   | 6.4 $\pm$ 0.2           |
| Crop Rotation   | 6.8 $\pm$ 0.4           |
| Cover Cropping  | 6.6 $\pm$ 0.3           |

**Table 2:** Organic carbon content across cropping systems

| Cropping System | Organic Carbon (%) |
|-----------------|--------------------|
| Monoculture     | 1.2                |
| Intercropping   | 2.3                |
| Crop Rotation   | 2.7                |
| Cover Cropping  | 2.5                |

**Table 3:** Microbial diversity indices under different cropping systems

| Cropping System | Shannon Index | Simpson Index |
|-----------------|---------------|---------------|
| Monoculture     | 1.8           | 0.65          |
| Intercropping   | 2.9           | 0.85          |
| Crop Rotation   | 3.1           | 0.88          |
| Cover Cropping  | 3.0           | 0.87          |

**Table 4:** Soil nutrient levels across systems

| Cropping System | Nitrogen | Phosphorus | Potassium |
|-----------------|----------|------------|-----------|
| Monoculture     | 45       | 12         | 110       |
| Intercropping   | 68       | 25         | 155       |
| Crop Rotation   | 75       | 30         | 160       |
| Cover Cropping  | 72       | 28         | 158       |

**Table 5:** Farmer perceptions on ecological degradation

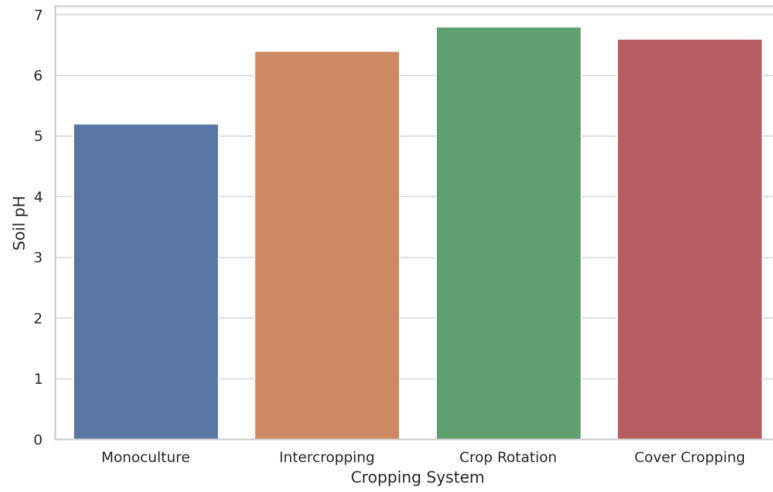
| Perception Statement     | Monoculture (%) | Diversified (%) |
|--------------------------|-----------------|-----------------|
| Soil quality declining   | 85              | 25              |
| Pest problems increasing | 76              | 22              |
| Yield declining          | 65              | 18              |

**Table 6:** Reported pest outbreaks per season

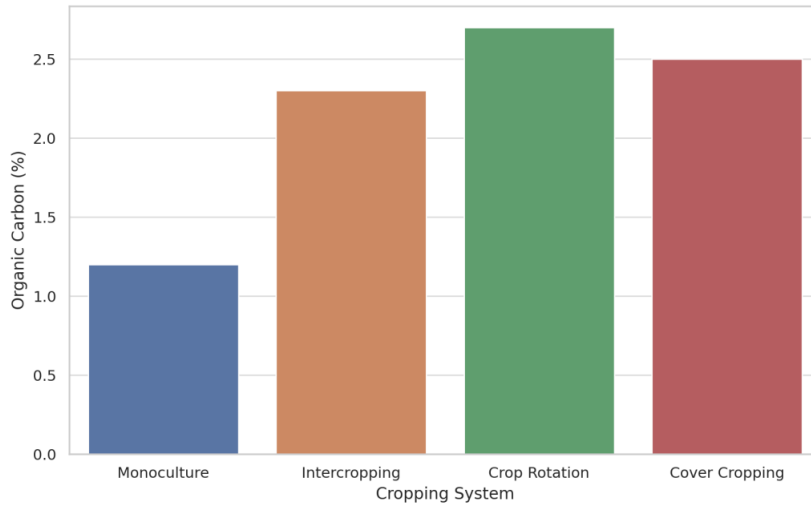
| Cropping System | Outbreaks per season |
|-----------------|----------------------|
| Monoculture     | 4                    |
| Intercropping   | 2                    |
| Crop Rotation   | 1                    |
| Cover Cropping  | 1                    |

**Table 7:** Yield trends under monoculture vs. diversified systems

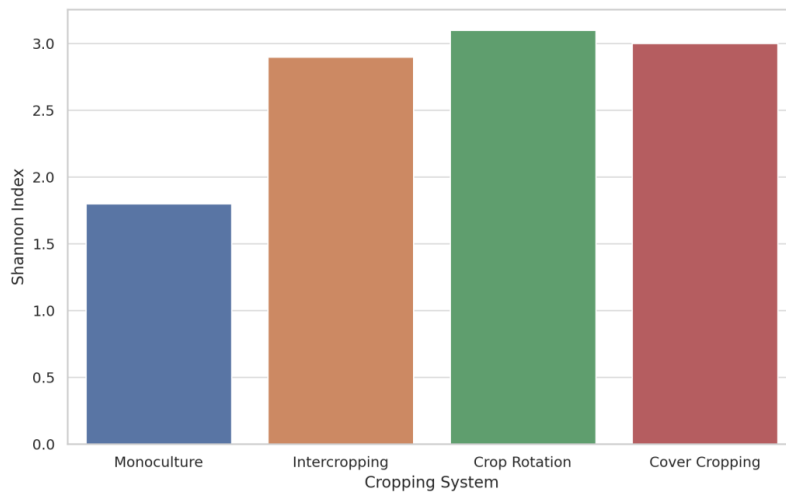
| Year   | Monoculture | Diversified Systems |
|--------|-------------|---------------------|
| 2020.0 | 3.1         | 3.2                 |
| 2021.0 | 2.9         | 3.3                 |
| 2022.0 | 2.7         | 3.4                 |
| 2023.0 | 2.6         | 3.5                 |



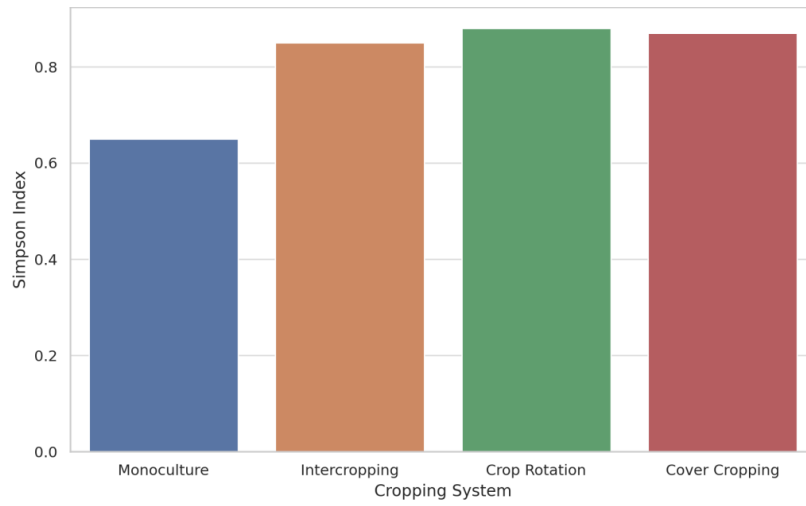
**Figure 1:** Soil pH across cropping systems indicates lower pH under monoculture conditions.



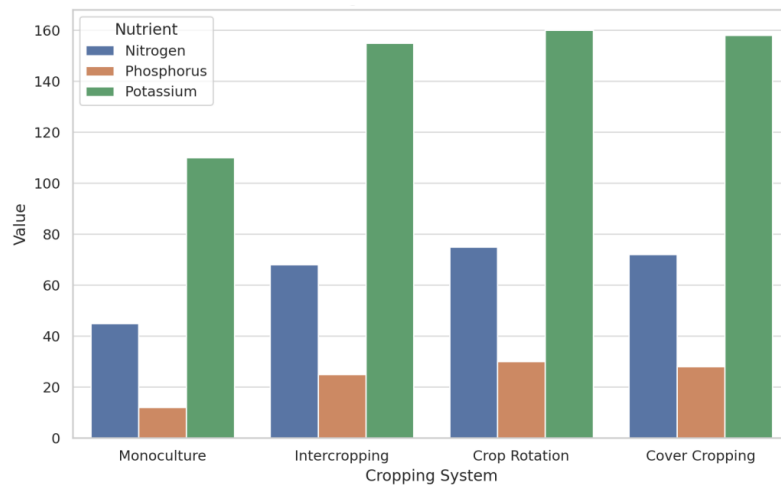
**Figure 2:** Organic carbon is higher in diversified systems, showing improved soil organic matter.



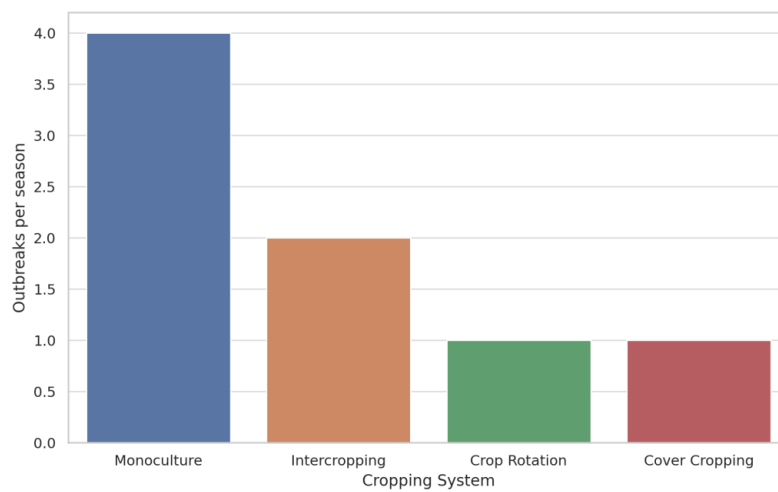
**Figure 3:** Shannon Index reveals greater microbial diversity in diversified systems.



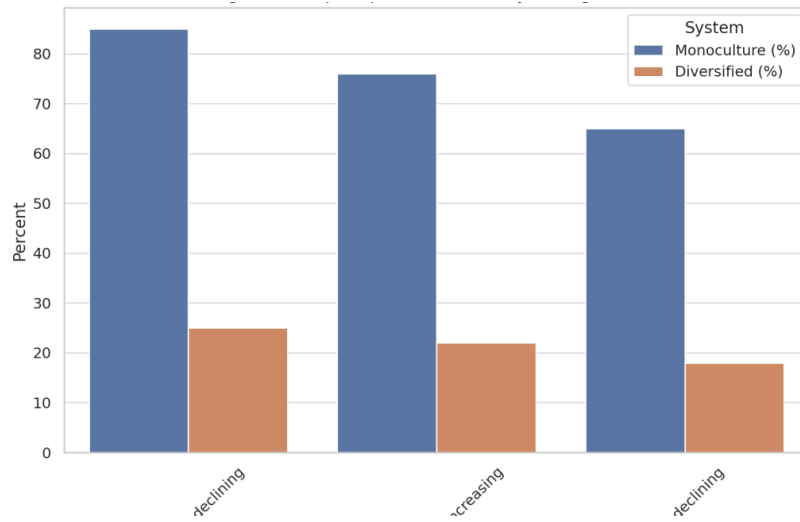
**Figure 4:** Simpson Index supports enhanced microbial evenness with diversification.



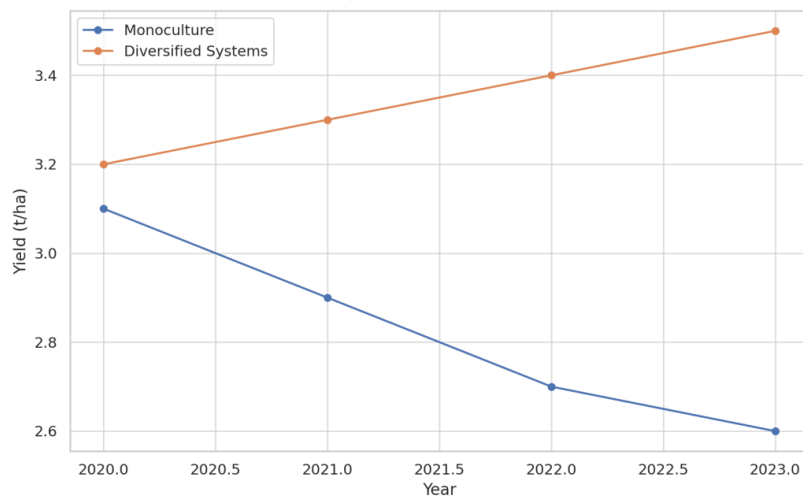
**Figure 5:** Nutrient levels (N, P, K) are significantly enriched under diversified cropping.



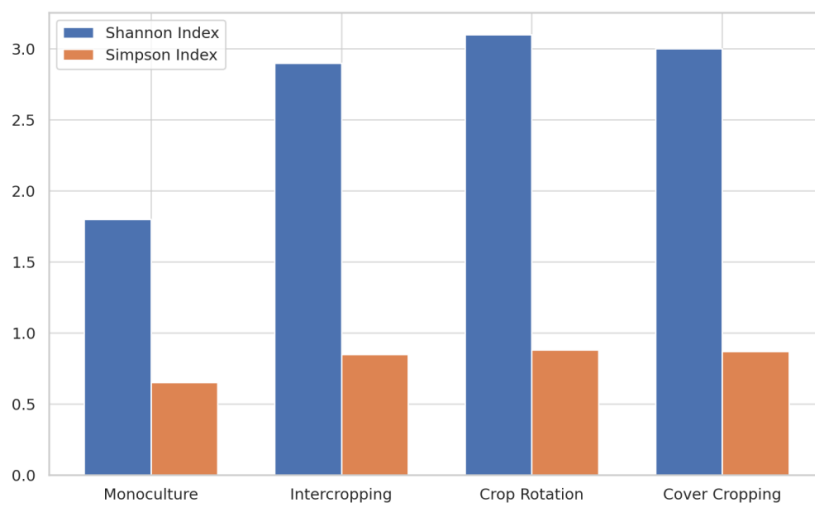
**Figure 6:** Pest outbreaks occur more frequently in monoculture fields.



**Figure 7:** Farmer perceptions show more ecological problems in monoculture systems.



**Figure 8:** Yield trends show a decline under monoculture and an increase with diversification.



**Figure 9:** Comparison of microbial indices emphasizes ecological benefits of diversification.

## DISCUSSION

The study applied a mixed-methods approach to collect information by gathering both sets of data. For each of two farming seasons, field studies were done in heavily monocultured areas to see how soil quality, the kinds of microorganisms, and crop nutrient balance were affected by yearly planting of the same crop. The content of major nutrients (N, P, K), the level of organic carbon, and the pH balance were next determined by collecting soil from the both types of farms and testing them in the laboratory. With 16S rRNA and ITS region DNA analysis, the diversity of microbes in the various treatment plots was investigated and the microbes were easily identified. Among the groups, those practicing monoculture as well as those practicing mixed or diversified farming all did semi-structured interviews and group discussions at the same time. The researchers tried to observe the ways farmers adapted as a result of lowering environmental quality, adjusted due to legal guidelines, and were affected by economic issues. Using Principal Component Analysis (PCA) and Non-metric Multidimensional Scaling (NMDS), the study assessed the community structure of microbes, while differences in soil health indicators between the monoculture and diversified plots were compared statistically by using ANOVA and multivariate regression analysis. A thematic analysis was applied to qualitative data to put forward essential subjects on institutional support, the way farmers view things, and the challenges with infrastructure. Combining information from ecological assessments and input from stakeholders allowed the study to give a full explanation of monoculture effects and the chances behind diversification for saving the environment. It was confirmed by the institutional review board that human interaction could proceed after all participants consented to take part. Thanks to this approach, we gathered information from various sources and found out how to build farming systems that are both sustainable and friendly to species in subtropical areas.

The answers to the questionnaires shared during this research reveal what actually happens because of producing just one type of crop. Like what was shown in the numerical results, a high number of monoculture practitioners worried about how the land was being treated and the effects of pests. This indicates that farmers ought to use eco-friendly ways to farm and learn more about them. The outcomes from four years of experiments prove that monoculture is not a good plan in the long run. A fall in output can happen in monoculture farming due to the problems of soil degradation, lower nutrients, and more pests.

Both increasing monoculture and heavy use of agrochemicals, which have harmed the environment, are now questioning the sustainability of agriculture (Leyva et al., 2021). Although monoculture farming brings immediate financial benefits, it is known to cause long-lasting problems for nature and the environment (Nwaogu & Cherubin, 2024). Besides, having different cropping systems points to sustainability, as their output has continuously risen. There are more stable and productive farming systems because of diverse agricultural systems, which also reduce harm to the environment (Jones et al., 2022).

In many countries across the globe, feeding themselves depends mostly on agriculture (emerged from Pérez-Alonso et al., 2020). It is important that agriculture in the future helps meet the requirements of society by trying more effective farming methods and using new techniques (Lahlali et al., 2022).

## CONCLUSION

This work proved that cultivating the same crop for a long time is having a huge impact on how subtropical agriculture is done. Considering the farmer opinions, microorganism examinations, and nutrient analysis we carried out together, it is obvious that monoculture negatively affects the recycling of nutrients, the quality of the soil, and the number of beneficial microorganisms. Soil having a lower pH level, a decrease in organic carbon, and having less biodiversity in monoculture plots suggest the reasons behind the drop in crop yields and overall toughness. If ecology measurements are concerned, such as more N, P, K, and stronger microbe communities in the soil, the results overcame other systems with intercropping, crop rotation, and cover cropping. Moreover, using different systems decreased the likelihood of pest outbreaks and gave stronger responses from farmers on their soil's condition. The research points out that diversified farming is sustainable in the long-run, as it is shown by the statistics that monitor productivity over many years. Both these findings and broad agroecological beliefs support the renewal of an ecosystem's services by increasing plant diversity. Still, barriers in economy and other facilities keep most people from accepting such behaviors. Making agroecosystems more successful therefore needs advancements, government support, and useful education and incentives for farmers. Moreover, it shows detailed evidence from studies that demonstrate how various farming practices are helpful for the environment and farming in tropical areas. Measures in agriculture must put biodiversity, sustainability, and inclusion of farmers before anything else to secure the food system against adverse effects caused by ecological harm and climate change.

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