

Diversification of cropping systems to improve national food security Diversificación de los sistemas de cultivo para mejorar la seguridad alimentaria nacional

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Abstract

The aim of this reflection is to study and promote the diversification of cropping systems as a strategy for the improvement of food security at national level. Food security is a global challenge that nations continue to address. Agricultural systems should address this issue; however, traditional practices may not be sufficient to produce enough food for the growing population. Conversely, intensive agriculture has significantly impacted the environment by increasing the use of fertilizers and freshwater, expanding cultivation lands, and reducing biodiversity. Therefore, innovative techniques are necessary to enhance agricultural productivity while respecting planetary environmental limits that are essential for the resilience of the earth. Enhancing cropping diversity in agricultural systems could significantly increase yield and food production, optimizing land usage efficiency. This brief analysis examines the diversity of crop species in Colombia from 2006 to 2022 and its impact on agricultural production. National crop diversity has increased over time, with higher heterogeneity observed in regions such as Cundinamarca, Boyacá Antioquia, Santander, Nariño, and Valle del Cauca. Additionally, significant correlations exist between the number of crops cultivated per location and agricultural production, emphasizing the significance of diversity in food systems. Increasing crop diversity can not only improve national food security but also aid in maintaining ecosystem integrity. Further research should focus on assessing the impact of various farming system diversification, approaches on yield stability and food security at the farm level.

Resumen

El objetivo de esta reflexión es estudiar y promover la diversificación de los sistemas de cultivo como estrategia para la mejora de la seguridad alimentaria a nivel nacional. La seguridad alimentaria es un desafío global que las naciones continúan abordando. Los sistemas agrícolas deberían abordar esta cuestión; sin embargo, las prácticas tradicionales pueden no ser suficientes para producir suficientes alimentos para la creciente población. Por el contrario, la agricultura intensiva ha tenido un impacto significativo en el medio ambiente al aumentar el uso de fertilizantes y agua dulce, ampliar las tierras de cultivo y reducir la biodiversidad. Por lo tanto, se necesitan técnicas innovadoras para mejorar la productividad agrícola respetando al mismo tiempo los límites ambientales planetarios que son esenciales para la resiliencia de la Tierra. Mejorar la diversidad de cultivos en los sistemas agrícolas, podría aumentar significativamente el rendimiento y la producción de alimentos, optimizando la eficiencia en el uso de la tierra. Este breve análisis examina la diversidad de especies de cultivos en Colombia de 2006 a 2022 y su impacto en la producción agrícola. La diversidad de cultivos nacionales ha aumentado con el tiempo, observándose una mayor heterogeneidad en regiones como Cundinamarca, Boyacá Antioquia, Santander, Nariño y el Valle del Cauca. Además, existen correlaciones significativas entre el número de cultivos cultivados por ubicación y la producción agrícola, lo que enfatiza la importancia de la diversidad en los sistemas alimentarios. El aumento de la diversidad de cultivos no sólo puede mejorar la seguridad alimentaria nacional sino también ayudar a mantener la integridad de los ecosistemas. Futuras investigaciones deberían centrarse en evaluar el impacto de diversos enfoques de diversificación de los sistemas agrícolas, en la estabilidad del rendimiento y la seguridad alimentaria a nivel de finca.



Introduction

Global food security is a pressing challenge on the global agenda due to the world's population estimated to reach ten billion by 2050 [1-3]. Various approaches are emerging, and knowledge is expanding, resulting in several proposed solutions to address this issue. It is essential not only increase the quantity of food produced but also guarantee its quality and accessibility [4]. Meeting these demands necessitates agricultural systems with increased yields that simultaneously minimize cultivation area expansion [5]. It is well known that expansion and intensification of agriculture are significant contributors to biodiversity and habitat loss, soil and freshwater degradation, environmental pollution, and greenhouse gas emissions [6]. Hence, a new approach to crop production is imperative.

Traditional agricultural practices rely on expanding and intensifying the use of fertilizers, pesticides, and water inputs to enhance crop yields. Worldwide, over 700 million hectares are utilized for cultivating the five major cereal crops: maize, wheat, rice, barley, and sorghum. These crops provide roughly 50% of the world's caloric intake [7]. However, addressing food insecurity requires more than just increasing the productivity of primary crops. Diversifying crops by incorporating alternate species has the potential to improve food quality, decrease reliance on a limited number of staple crops, maintain cultural dietary diversity, and cultivate natural climate-resilient crops. As well as, in order to maintain the resilience of the planet and avoid exceeding planetary limits such as land-system change, biosphere integrity, and freshwater use, among other factors, innovative agricultural practices must be developed [2].

The diversity-stability relationship can aid in understanding the influence of biodiversity on system productivity and stability. This relationship has been studied by analyzing how crop diversity reduces variability in productivity over time, protecting crop production from environmental stressors [8]. Increasing crop diversity is critical in achieving food security and addressing global challenges, such as rising food demand, hunger, and malnutrition. Also, this method can reduce harmful environmental effects [6,9].

Prior studies show that enhancing national-level crop diversity leads to more stable yields over time and higher agricultural output [10], mitigating the dangers posed by

severe weather and other production threats. Consequently, this helps maintain a constant food supply [9]. Furthermore, research has shown that increasing crop diversity within agricultural systems can strengthen the financial stability of farmers in Mexico and India by improving crop production, yields, and overall economic outcomes [11-13]. However, other research suggests that the relationship between crop diversity and yield stability is not universal. Instead, it varies depending on the spatial scale and parameter of interest [10]. The aim of this reflection is to study and promote the diversification of cropping systems as a strategy for the improvement of food security at national level and encourages the adoption of innovative techniques that not only increase agricultural productivity, but also respect environmental limits that are critical to the resilience of the Earth.

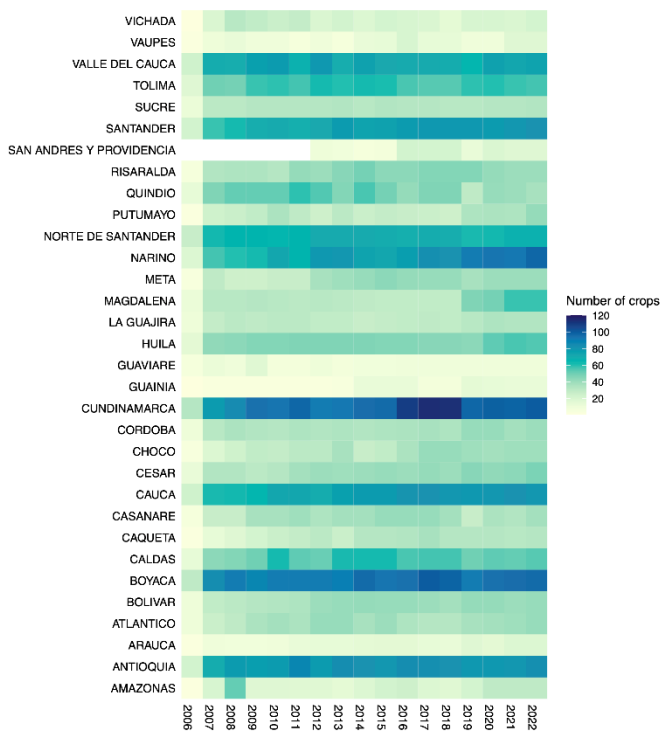
Impact of the cropping system diversity on national agricultural production

Colombia possesses one of the most abundant biodiversity worldwide, with around 22,840 plant species identified [14]. The cultivation of 245 distinct crop species in the country between 2006 and 2022 highlights the existence of a broad range of agricultural systems [15]. Agricultural diversification involves adding functional biodiversity to cropping systems by increasing the number of species at various spatial and temporal scales for maximizing benefits [6]. In the present study, Colombian agricultural data from 2006 to 2022 were analyzed to evaluate the impact of crop diversity on productivity and yield. This database was developed and administered by the National Agricultural Ministry and store information about agricultural production in Colombia by crops and locations [15]. Data analysis was conducted using the software R and the library ggplot2 [16,17].

Between 2006 and 2022, Cundinamarca and Boyacá had the highest crop heterogeneity, followed by Antioquia, Santander, Nariño and Valle del Cauca. Conversely, crop heterogeneity in Colombia has increased over time, with the highest values occurring in 2017 and 2018 (see Figure 1). Positive and significant correlations were found between the total production and yield of crops with the number of cultivated species at various locations in Colombia (see Figure 2), suggesting that crop diversity may have an impact on the amount of agricultural products, aiming to improve food security. This analysis highlights the impact of crop diversity at the regional

level and serves as a starting point for further exploration of the situation at the farm system. Previous research indicates that crop heterogeneity, whether at the farm or larger scale, may enhance the resilience of both total production and farm income even under unfavorable climate conditions [11]. Furthermore, diversification not only benefits agricultural production but also increases ecological tolerance to environmental stressors.

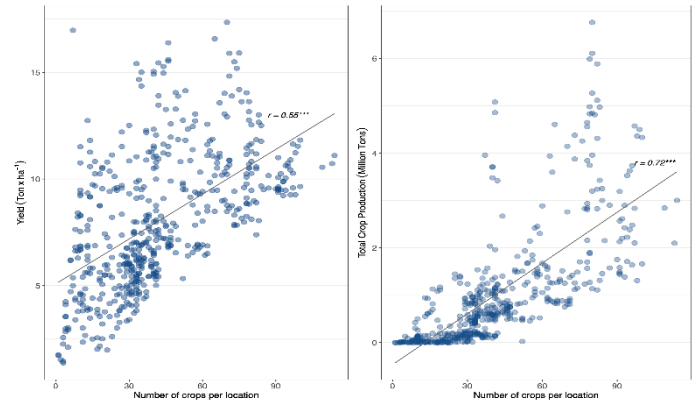
Figure 1. Number of crops cultivated by location and year in Colombia from 2006 to 2022



This method of agricultural production may address the demand of an expanding global population, which has altered food consumption habits [5]. Furthermore, it holds significance within the context of the 2030 Agenda for Sustainable Development, primarily for the objectives of Zero Hunger and Life on Land. Also, a thorough comprehension of the correlation between crop diversity and production is essential for formulating policies aimed at enhancing national agricultural activities. Nevertheless, a successful agricultural policy must address the diverse

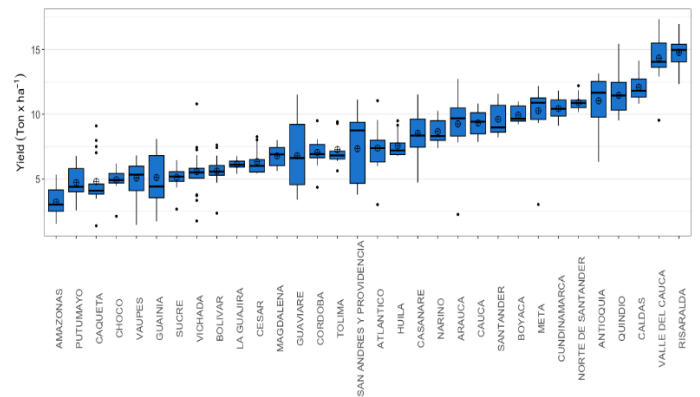
needs of distinct locations, thus necessitating the characterization of farms across Colombia.

Figure 2. Yield and total crop production correlation with numbers of crops per Colombia's locations. r indicates Pearson correlation value and *** significant correlation at $p < 0.001$.



Locations in Colombia with greater heterogeneity in the cropping system showed high yield values from 2006 to 2022, as demonstrated in figure 3.

Figure 3. Yield between 2006 and 2022 at Colombian locations. Crossed circles indicates means for yield per Colombia locations



For example, Valle del Cauca presented values exceeding 15 tons per hectare in crop production, signifying optimal efficiency with the available agricultural land. In addition, Antioquia exhibited significant yield variability in the cropping system. During the observed time period, regions with a low number of crops, such as Guaviare, Guainia, and Vaupes, exhibited a low yield. Notably, Arauca and Choco showed the opposite trend of the relationships shown in figure 2. Focusing on yield as a means of influencing agricultural activities is essential because it highlights the influence of climatic and non-

climatic factors on crop production, which is invaluable for decisions to improve farmers' practices [18].

Diversity is known to provide stability in natural ecosystems, but the connection between crop diversity and yield stability is still unclear across spatial scales in agricultural systems [10]. Thus, conducting additional analysis at the farm level is necessary to determine cropping diversity's impact on yield and food security. Agricultural data exploring the effects of rotational diversity and intercropping practices on farms in Colombia can aid in the analysis of the connection between diversity and yield stability. Research has demonstrated that these cropping systems improve yield stability under stressful conditions.

The mechanisms explaining this relationship include an increase in the prevalence of beneficial insects, enhanced soil moisture retention, and differential tolerance to abiotic and biotic factors [10]. Other agricultural practices, such as mixed cropping, companion crops, catch crops, trap crops, and variety mixtures, have been reported to diversify farming systems [19] and potentially enhance crop yield stability. Investigating the implementation of these practices on farms in Colombia could reveal methodologies for improving food security.

Expanding cropping diversity by incorporating more plant species into agricultural systems could be a key strategy in tackling hidden hunger. In developing nations where the diet primarily relies on cereals, nutrient and bioactive intake is insufficient leading to occurrences of hidden hunger. Nutritional-sensitive agriculture could be one approach to address this problem. This approach emphasizes the importance of diversifying agricultural system promoting the cultivation of underutilized crops [20]. The crops, such as fruits and vegetables, produce food that includes bioactive compounds such as flavonoids and carotenoids. These compounds provide various health benefits to humans such as improving cardiovascular health and protecting against metabolic syndromes [7].

On the other hand, it is calculated that current global food production has reached an energy equivalent of 5,000 kcal per person per day, but the difference in per capita consumption between the richest and poorest countries is still large. In addition, 800 million people in the world are undernourished, and 250 million children under the age of five are malnourished or have restricted growth [21]. An approach to global food security should focus not only

on production volume, but also on food quality, creating healthy, sufficient and diverse food systems. However, there are other parameters that should be considered to strengthen food security, such as: food availability, access, distribution, and utilization.

Conclusion

The study provides an overview of how an increase in cropping diversity could impact national agricultural production. Locations in Colombia that cultivated a larger number of crop species between 2006 and 2022 exhibited higher total production and yield, emphasizing the significance of diversified agricultural systems. Nevertheless, future research on agricultural activities in Colombia should emphasize the importance of crop diversity across different temporal and spatial scales in maintaining yield stability and food security.

To enhance the knowledge about agriculture and food system in Colombia and improve food security and rural development, researchers, farmers, and national authorities need to understand national cropping systems, the impact of smallholder and industrial agriculture on national production, the typologies and functional characteristics of farms, and the contribution of regional agricultural systems to food system stability. On the other hand, this information is essential for designing policies that ensure food security in Colombia, not only by increasing the quantity but also the quality of agricultural products, while also preserving the integrity of the biosphere and using agricultural land and freshwater resources sustainably.

Consent for publication

The author read and approved the final manuscript.

Competing interest

The author declare no conflict of interest. This document only reflects their point of view and not that of the institution to which he belongs.

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