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How Terrestrial Ecosystem Ecology can be applied to Sustainable Agroecosystem Management

The technological advancements that have come out of the Green Revolution have led to an economy of scale allowing for the industrialization of agriculture. However, at the cost of increased production, industrialized agriculture contributes heavily to environmental degradation including topsoil loss, eutrophication, loss of biodiversity and increased greenhouse gas emissions. Sustainable management can be enhanced if these agricultural systems are recognized as *agroecosystems* and managed as such. Terrestrial ecosystem ecology has the potential to offer significant insights into how this can be achieved.

Concept of Scale

The environmental impacts previously mentioned manifest at regional to global scales, even though the sources of these problems (i.e. the industrialized practices) operate at the acre or farm-wide scale. The terrestrial ecosystem concept of scale can be utilized in this context as it recognizes that agroecosystems are not static isolated units of area. If farms can be recognized as open systems comprised of interacting biotic and abiotic factors that are not confined to a discrete parcel of land, sustainable management of said land is more likely. Ecologists understand that the scope or scale of analysis depends on the level of biological organization – one would not use the same scale to analyze a cell as they would a forest. Viewed as agro*ecosystems*, holistic management strategies of farms should invoke a scope that encompasses a large spatial and temporal scale. This scope should take into account surrounding landscape features such as forest patches, native grasslands and wetlands and the biodiversity within them, as well as, the history of the land. On the other hand, recognizing that an agroecosystem is not a homogenous area, smaller scale management practices that consider heterogeneity in resources, topography, potentially soil type and crop trait differences are additional vital considerations. For example: Titia has monitored the differences in soil quality from various parts of her farm and has taken these considerations into account when adding compost and basalt pebbles to enhance organic matter and clay content, respectively. She does not simply "dump" the same amount everywhere. In addition, she recognizes patches of forest (agroforestry) and wetlands as vital parts of the agroecosystem that provide pollinators and wildlife species that help control pests.

Concept of Ecosystem Resilience

Another terrestrial ecosystem concept that can provide significant insight into sustainable agroecosystem management is centered around the concept of ecosystem resilience. It can be defined as the "capacity of a socio-ecological system to maintain similar structure, functioning and feedbacks despite shocks and perturbations" (Chapin et al. 2011). By applying this definition to agriculture, resilient agroecosystems can "handle" environmental perturbations like drought, pests and disease, providing insurance for farmers and the people that they produce food for. A study conducted by Jacobi et al. (2015) examined the level of resilience, especially with respect to climate change, of different cocoa farming methods in Bolivia. Using various indicators of resilience, such as soil bulk density (used to estimate vulnerability to erosion), tree species diversity, crop diversity, yield and occurrence of *Moniliophthora perniciosa* (a cocoa tree pathogen), it was found that farms using agroforestry had the highest resilience and yields (Jacobi et al. 2015). Diversity, in terms of genes, crop varieties and wild species enhances resiliency by providing a variety of species or individuals adapted to a wide range of environmental conditions. In the event of a drought or disease outbreak, the likelihood of intensive crop failure is reduced, as some individuals can survive the environmental stress. From the reports of high yields on Evan and Titia's farms, it is evident from their application of this concept of resiliency – through mixed cropping and the use of agroforestry – that there is not only potential for maintaining agroecosystem integrity, but also enhancing farmer livelihoods and incomes.

Concept of Biological Control over Nutrient Pools and Fluxes

The final terrestrial ecosystem concept that I would recommend applying to sustainable agroecosystem management is focused around nutrient pools and fluxes. Terrestrial ecologists recognize that soil and plant nutrient dynamics are mediated by the soil microbe community and that in the short-term, the rate of nutrient flux is largely controlled by them. Microbes facilitate either net mineralization or net immobilization depending on the relative soil/litter nutrient stoichiometry. Net immobilization occurs when carbon:nitrogen (C:N) ratios are greater than 25:1 (i.e. scarce N is taken up from the soil by microbes and isn't available to plants) (Grogan 2016). Net mineralization occurs when C:N ratios are less than 25:1 (i.e. N is no longer limiting, hence microbes secrete N and make it available for plant uptake) (Grogan 2016). Managing organic matter inputs through compost application requires this threshold value to be taken into account in order to optimize net mineralization. Moreover, knowing that 50-75% of the N fertilizer added is lost either from leaching or denitrification suggests that applying more fertilizer is often futile (Hirel et al. 2011). Instead, farmers like Evan implement practices that activate the microbial community through the application of biostimulants that can (if used in appropriate concentrations) stimulate selective microbes that initiate net mineralization of nutrients (Chen et al. 2002). Tillage, in addition, breaks up mycorrhizal networks that help to connect plants with discontinuous nutrient patches. Evan, Titia and Charlie all implement various practices that seek to minimize soil disturbance, thus preserving soil microbe community function. Charlie implements no-till seeding and Titia minimizes the area that is walked on, reducing soil compaction.

In summary, terrestrial ecosystem ecology offers insights for sustainable agricultural management by noting that ecological processes, including agroecological ones, are dynamic and comprised of many interacting abiotic and biotic factors. Consequently, due to the complexity of these processes, predicting which management practices are the most effective is challenging, especially since the payoffs do not usually arise until many years and harvests later. For example, Titia will not know instantly whether her compost "recipe" is successfully enhancing soil fertility. Thus many innovative farmers have to take risks when trying new sustainable practices. Some farmers may not have the financial security to undertake these risks and therefore may wish to continue using more unsustainable practices. If more ecological research went into testing the efficiency of these practices and if ecologists worked with farmers then perhaps sustainability in agriculture could proliferate and lead not only to environmental protection, but enhanced farmer-scientist engagement.

References

Chapin, F. S. III, Matson, P. A. and Vitousek, P. Springer. 2011. *Principles of Terrestrial Ecosystem Ecology*. 2nd edition. New York: Springer-Verlag.

Chen, S., Subler, S. and Edwards, C. A. (2002). Effects of agricultural biostimulants on soil microbial activity and nitrogen dynamics. Applied Soil Ecology 19:249-259.

Grogan, P. 2016. Terrestrial Ecosystems: 8. Decomposition and Plant-Soil Interactions. Presentation.

Hirel, B., Tétu, T., Lea, P. J. and Dubois, F. (2011). Improving nitrogen use efficiency in crops for sustainable agriculture. Sustainability 3:1452-1485.

Jacobi, J., Schneider, M., Bottazzi, P., Pillco, M., Calizaya, P. and Rist, S. (2015). Agroecosystem resilience and farmers' perceptions of climate change impacts on cocoa farms in Alto Beni, Bolivia. Renewable Agriculture and Food Systems 30:170-183.