Multilevel Habitat Management as a Paradigm for Developing Regenerative Crop Production Systems

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The ongoing improvement of crop production systems has allowed for continual increases in productivity in horticulture. The relatively high returns per hectare for horticultural crops have allowed intensive use of a number of inputs to achieve this higher productivity. However, the increasing costs of those inputs as well as increasing concerns about the environmental and human health impact of some inputs have sparked interest in developing alternative crop production systems. The need to maintain farm viability while mitigating deleterious off-farm effects and long-term consequences has led some researchers to reconsider the R&D models commonly in use.

The most common model is based on understanding plant-scale (plant physiological or soil) processes (basic research) and extending it to field-scale levels of management (applied research). The basic research needed to understand higher order interactions of plants (as individuals, populations, or communities) with their environment has until recently remained largely within the purview of geneticists and ecologists. The recent growth in interest in agroecology and systems approaches as areas of research has increased the need for basic and applied research to support continued research and development efforts in these areas.

Adding agroecological principles to current horticultural research activities does not imply abandonment of features of current R&D models; rather, it requires implementing a balanced effort between conducting component vs. systems-level programs. The objectives of many research projects in the past have focused on one of these two extremes; more recently a larger percentage of project objectives stated in the literature list integration of component technologies into systems approaches for improving crop production systems. However, changes in the broader environmental, economic, and sociological system within which crop production systems operate require explicit changes in the R&D models used, to optimize the chances of successfully developing and implementing regenerative crop production systems in as timely a fashion as possible (Lowrance et al., 1986).

Horticulture operates within an organizational hierarchy that includes biological/ecological management levels that are above, and below, the exclusively plant- (or field-) scale focus of most basic (or applied) research projects. While some researchers may consider the effects of other levels (e.g., of neighboring fields or farms), these

variables usually are not included in the list of project objectives, nor are other disciplines included in the design phase of the experiment. By explicitly considering the multiple levels in which horticulture operates we can 1) better define projects that address critical issues at more than one level, 2) facilitate interdisciplinary collaborations, and 3) develop a framework to integrate systems-level and component research.

This paper presents a discussion of the types of agroecosystems that are most relevant to horticulturists and focuses on the biological/ecological aspects of the multiple levels of organization for horticulture. Each of these bio/ecological levels forms a "habitat" that is affected by changes at levels higher, and lower, within the hierarchy.

The multiple levels of (rural) habitat management

There are at least nine sublevels of habitat in which horticulture operates. Each of these can be further separated into aerial and subterranean factors at each level. The subterranean factor represents the below-ground portion of the scale envisioned by the aerial portion.

The only explicit term distinction needed between these two factors occurs at the smallest of the microhabitat sublevels: Plant part/product refers to the aerial factor; soil refers to activity that may be associated with a particular portion of the profile beneath the plant, such as crusting at the soil surface vs. microorganisms associated with the rhizosphere:

Habitat sublevels

- Continental
- Regional
- Watershed
- Valley
- Farm
- Field
- Row (or Bed)
- Plant
- Plant part/product (soil)

These nine can be aggregated into four bioecological levels of habitat when one considers what are the appropriate levels of organization at

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which to formulate and test hypotheses.

Mega-habitat

Continental
Regional

Macro-habitat

Watershed
Valley
Farm

Meso-habitat

Field
Row (or Bed)

Micro-habitat

Plant
Plant part/product (soil)

Horticulturists have typically focused their efforts at the micro-habitat (basic research) and meso-habitat (applied research) levels. However, they are now more likely to include macro-level factors in the objectives, if not the design, of experiments. This trend is important because we know that as conditions change at each level, conditions at other levels may be influenced, as illustrated below:

Mega $\longleftrightarrow$ Macro $\longleftrightarrow$ Meso $\longleftrightarrow$ Micro

In addition, changes at one sublevel may influence conditions at another sublevel or at a higher or lower level. An example that focuses on predominately subterranean factors would be: Reduced tillage practices that increase plant residue in a field to control soil erosion (meso/field) may affect the accuracy of seed or transplant placement (meso/row) and soil temperatures that affect seed germination (micro/plant). The same field-scale practice, if conducted on most fields where applicable, may decrease the soil loss on the farm (macro) and if done on enough farms may decrease soil loss in the watershed (macro).

An example of how the same field-scale practice may affect an aerial factor would be the potential increase in foliar disease inoculum caused by not incorporating previous seasons' crop residue into the soil. This disease potential might affect individual plants (micro) or entire rows or fields (meso).

Types of agroecosystems

When we begin manipulating habitats at more than the field scale we must consider the types of agroecosystems that we may be managing on a farm or watershed level. There are six agroecosystems that are relevant to horticulturists.

Forest/woodlot/rangeland
Orchard
Field crops
Vegetables

Professionally managed landscapes
Residential landscapes

These systems represent a continuum from most rural and least intensively managed (forest) to most urban and most intensively managed (residential landscape). For regenerative crop production systems, not only must other crops used in rotation (including field crops) be considered but also adjacent fields and farms (including nearby woodlots and residential clusters). For example, management of one system may alter the prevalence of an alternate host that affects crops grown nearby, such as the overwintering of plum curculio [*Conotrachelus nenuphar* (Herbst)], an apple pest, in nearby hedgerows.

The multiple levels of (urban) habitat management

While the agroecosystems illustrated above include both rural and urban systems, the habitat levels listed previously illustrate the levels germane to a rural setting. The model can also be used in an urban setting with minor terminology changes, as shown below:

Mega-habitat

Continental
Regional

Macro-habitat

*Municipality
*Neighborhood

Meso-habitat

*Household
*Planting area

Micro-habitat

Plant
Plant part/product (soil)

One brief example of interactions is the effect of pest population levels on one property (meso/household) on adjacent properties (macro/neighborhood).

Classical vs. multilevel habitat management

Classical views of habitat management would focus primarily on providing food and shelter for vertebrate wildlife. This has been extended recently to providing habitat for beneficial invertebrates, as illustrated in some of the other contributions to this colloquium. Both of these uses imply management at several levels of system hierarchy, e.g., cover crops provide soil protection across the field (meso) while each plant may provide nectar or pollen for certain life stages of beneficial insects (micro).

By explicitly studying the multiple levels of habitat in various agroecosystems we can provide a framework to: 1) better understand the complexity of the systems we are developing and modifying; 2) design component and systems-level research that are interdisciplinary in fact, because each participant has a clearly definable piece of the project; and 3) organize, interpret, and synthesize the information generated by systems-level and relevant component research.

Literature Cited

Lowrance, R., P.F. Hendrix, and E.P. Odum. 1986. A hierarchical approach to sustainable agriculture. *Amer. J. Alternative Agr.* 1(4):169-173.