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The Plant Community: a model for horticultural thought and practice in the C21st?

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Abstract

This paper discusses the idea of the plant community as a new design model for horticultural planting. It traces the origins of academic ideas about how semi-natural plant communities function in ecological terms and how increasingly the focus of research on these has been to understand the mechanics of change. The paper explores the advantages and disadvantages of horticulturally based plant communities, and looks at how key variables such as plant density and diversity, structural layers, and soil productivity affect both functional properties and also human aesthetic responses to the appearance of communities.

Keywords: design model, diversity, density

INTRODUCTION

Plant communities in the "wild"

The first work to explicitly conceptualise plant communities from a scientific perspective was published in Danish just before the end of the C19th (Warming, 1895). From the beginning of the twentieth century the study of the composition, and organization and these communities, how and why they change in time and space became the focus of the new science of Ecology. From early on there is a split between more mechanistic (British dominated) and more holistic, phyto-sociology (Continental European dominated) views of plant communities. The first phase of study involved description and building typologies of different community types (Sheald, 1987). Darwin (1859) had provided an overarching theory of how individual species change "through evolution by natural selection" but not on why and how specific changes occur in communities of organisms. In Britain, Tansley (1911) encouraged a focus on the mechanics of change in plant communities leading later in the century to the application of more experimentally rigorous approaches to ecology. An example of this are the aut-ecological (the ecology of the self) ideas embedded in CSR (Competitor; Stress tolerator and Ruderal) theory by Grime (1979) at the University of Sheffield.

These aut-ecological approaches involved, to some extent, a disassembling of the community into it's component parts to understand how these interact and how the community changes that result can be predicted. These approaches emphasised the traits (characteristics) of individual species and how these responded under given sets of circumstances. A range of models now exist, that provide a reasonably clear picture as to the likely outcomes for community change given specific environmental and management factors.

Plant community notions within the horticultural and design world

Notions of plants as communities are evident in the horticultural world before Warming (1895), for example, in William Robinsons "The Wild Garden" (1870). Robinson

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and his contemporaries travelled widely and would have seen many distinctive plant communities in nature. His flower meadow at Gravetye Manor takes its cues from the mountain meadows of the Alps, with narcissus and *Paeonia officinalis.* It is equally evident however that theoretical understanding of how these wild occurring communities "worked" was absent. Robinsons work involves a mixture of species being planted out to see what then happened.

The lack of accessible, readily applied to practice ecological theory, restricts progress within horticultural and design cultures to understand how to make designed plant communities until the end of the twentieth century. Understanding evolves through plant sociology perspectives twinned with horticultural and design trial and error by Richard Hansen in Germany. Hansen's work is practically based on long observation of plants in nature and in designed planting in the trial gardens at Weihenstephan, Munich. It shows understanding of the need to develop techniques to manage dominance through the design process. After the 1970's designed plant communities become closely associated with notions of nativism, and this delays integration of ideas about plant communities and horticultural plants. From the mid 1990's, research at the Department of Landscape, University of Sheffield, for example (Hitchmough, 2004) begins to test scientifically how relatively complex, horticulturally based designed plant communities can be made and how they behave in ecological terms. Dunnett and Hitchmough (2004) go on to provide a philosophical framework as to how designed plant communities can be used in the urban landscape.

What are the advantages and disadvantages of nature-like plant communities?

Plant communities in nature exist across a spectrum from the structurally and taxonomically simple to the highly complex. As a general principle, as soil productivity (the capacity to produce plant biomass) increases, taxonomic diversity decreases. Horticultural and design interest in communities as a source of inspiration have however focused mainly on the more species complex (Dunnett and Hitchmough, 2004), but such communities often pose problems of stability in the largely highly productive soils of urban landscapes.

In traditional horticultural planting that utilizes shrubs or herbaceous plants, the "community" is generally composed of monocultural blocks (read "patches" in ecological theory) of species. These vary greatly in size. In North Western European modernist landscape architecture, the plants forming these were often monocultures of evergreen shrubs, selected to be long persistent and used on a very large scale, often as part of urban infrastructure. In nature, near monoculture communities are largely restricted to highly productive environments, such as mesotrophic-eutrophic wetlands, which are dominated by a few of the most productive species. These near monocultural communities have a number of strengths, especially in highly productive urban soils where dominance is readily attainable and can temporarily halt successional change. The simplicity of this type of planting provides cues to urban dwellers around order and control, and this is a cherished virtue in the minds of many urban people (O'Brien, 2012). Where block size is too large such vegetation is however seen as boring. From a maintenance point of view monocultures are conceptually easy to maintain; any species present that looks different to the dominant species in a block are by definition invaders to be removed.

As vegetation becomes more diverse in terms of species and structures most people perceive this as being more natural and therefore more resilient to invasion by weeds than plantings that are less natural looking. These ideas have their origins in mis-interpretations of ecological discourse. Unfortunately when you look at the ecological literature in detail, in most cases the opposite is true, i.e. vegetation is most resilient when relatively simple taxonomically and structurally. This view has been encouraged by the ecological literature which has frequently sought to show how biodiversity is valuable because it makes plant communities work "better", as a way to give utilitarian and political value to biodiversity (Rajan-Koppler and Hitchmough, 2015). This is not to say that taxonomically and structurally complex vegetation cannot be low management, but rather than it is heavily contingent on the environment in which it made, what is made and its management.

For complex multi-species vegetation to persist in the first place, there is a need to have spaces within the vegetation into which species emerge and grow prior to canopy closure. These gaps are inevitably invasible by weeds at various points in time, particularly in highly productive soils with very high seed rain of the weedy ruderal species that now dominate urban floras. By contrast monocultures involve large biomasses of a species which are either evergreen or persist as deep winter litter, and effectively restrict invasion. When complex plant communities occur naturally, they are mostly restricted to unproductive soil and low rainfall, that inhibit the invasion of weeds, but when such vegetation is transferred to more productive, moister soils in designed situations, these benefits are lost.

The only way to reliably reverse this situation is to i) reduce productivity where possible, ii) utilize species selection and spatial organization to keep systems more closed for longer and iii) apply management techniques to restrict weed establishment in gaps (Rajan-Koppler and Hitchmough, 2015). So the challenge is how to use complexity but to still have communities that are economically manageable.

So what are the virtues of much more taxonomically complex designed communities? By definition these contain many more species per m^2 than monocultures. This allows the designer who understands how these communities function, to create a long succession of flowering, with species following species from spring to autumn. For the public more attractive seasonal events are generated, for longer periods of time for each m^2. This, plus the far more spatially complex structure resulting from the wide diversity of species present, provides superior habitat and foraging opportunities for invertebrates (Smith el al., 2006). The diversity and generally the density of pollinating insects (a conservation priority in many countries) is generally greatest with vegetation types that flower for a long period of time, have high sugar content nectar and the most protein rich pollen (Silva and Dean, 2000).

The repetition of plant species across a planting, allows a proportion of each species a better chance of finding a location to which they are fit. One of the main characteristics of urban landscapes is marked environmental heterogeneity, particularly in terms of soil conditions and light. Designers have to make a guess as to what conditions will be like in year zero, in full knowledge that these conditions will continue to change as large woody plants grow and cast ever larger areas of shade and soil water depletion zones.

A fundamental mismatch with these processes is the production of planting plans based on the block, in which only one species is planted in a given area of territory, and required to tolerate both the initial site conditions and then in the longer term, great environmental change generated by the planted or original plants. With the multi-species community, because a diversity of species are present in each m^2, species that are not well fitted are gradually outcompeted and replaced by their better fitted neighbours. These changes are gradual and largely invisible to the average viewer, an elegant solution to an inevitable and intractable process. The value of these potentially "self-repairing" plant communities are becoming increasing evident as planting in cities often has to deal with more extreme conditions than the biological near optimum that horticulture has traditionally sought. Take for example sustainable drainage swales, which contain complex moisture gradients within each part of the swale. Due to the built in capacity for adaptation to the site as found, these communities (but not the individual species) may appear to be immortal. As shorter-lived species die their space is borrowed by longer lived, and or better fitted species. This can however only work when plants with appropriate traits are used to build the community.

The disadvantages of designed naturalistic plant communities is that many people find the more disordered appearance associated with high spatial and taxonomic complexity to be unattractive in intensely cultural, ordered urban spaces. Özgüner and Kendle (2006) have shown that these averse reactions to the lack of what Nassauer (1995) referred to has "cues to care" can be overcome in herbaceous vegetation through designing in high levels of flower colour. A further disadvantage is that maintenance staff find these plantings much more difficult to conceptualise in terms of what is a weed and what isn't.

What are the research and practice challenges in designing and managing complex plant communities?

Whilst there is much commonality underpinning the design of plant communities, specific issues depend on the scale of the plant communities in question (for example woodland, versus heathland v meadows) and the geographic-climatic context, for example, temperate, Mediterranean, sub tropical and tropical. In the early C20th within research on communities there was a sense that the their properties were more than the sum of the component plant species. An example of this might be the fact that mixed communities tend to support a larger biomass per unit area than the same area of a monoculture (Cardinale et al., 2007). In the main however what happens within communities is strongly related to the aut-ecological properties of the component species.

Density

Plant density has a critical effect on the properties of designed communities. Using the example of herbaceous plants and dwarf shrubs in urban landscapes most conventional plantings are made at densities that are much lower than those associated with naturally occurring communities containing broadly similar plant types. Planted herbaceous vegetation for example, typically involve between 6-12 plants per m^2, whereas meadows, or tall forb vegetation, generally have plant densities >150 plants per m^2, and potentially much more.

The consequences of these differences between naturally occurring and cultural planting densities have been little studied in horticulture. Research to increase the sustainability of agricultural crops has explored the potential of increasing crop densities to increase competitive pressure on weeds (Weiner, 1998). Differences in density and plant size between desired plants and weeds leads to competitive asymmetry, with competition for light the mechanism by which plant mortality occurs. The author has undertaken similar experiments with sown perennial herbaceous vegetation and density is very powerful in terms of reducing short and long term weed invasion (Hitchmough, 2006). The same processes simultaneously eliminate shade intolerant desired species as density increases.

High plant density can only be exploited to the full when techniques such as sowing, are used. Density is something of a conundrum, which requires much more empirical research to identify critical threshold densities for the persistence of a range of communities and species at different productivity levels.

Layering

Density is also closely associated with layering within designed plant communities. With the exception of the most unproductive sites, most semi-natural vegetation consists of more than one layer of species canopies overlapping each square metre of ground space. This is most obvious in woodland, but also occurs in heathlands and herbaceous plant communities such as meadows. These forms of spatial organization are a product of natural selection. The tallest species in a vegetation stratum generate shade and this leads to reduced competition (in terms of Grime's (2001) view of competition) in the lower canopy layers that can be occupied by slow growing more shade tolerant species. Even in very dry steppe communities that superficially seem to be one layer only, the ground layer is often rich in bryophyte species. From a design and management perspective this stacking up of layers on top of one another maximizes light extinction at ground level. This reduces establishment of the shade intolerant weedy ruderal species that predominate in urban environments.

These multiple layers also allow extra species per m^2 to be incorporated that drive long seasons of floral interest for people, plus complex physical structures to maximize opportunities for invertebrates and other animals. These processes are largely scale independent, i.e. they are much the same for when you design woodlands or meadows. Layering is clearly a valuable property to develop in designed urban vegetation both for functional and aesthetic reasons, but to do this requires phenological, and morphological understanding of capacity to tolerate shade at various times of the year.

Trait characteristics

Dealing with density and canopy layers eventually leads to a need to identify species with tolerance of shade and other key environmental factors that ecologists often call traits. The trait concept is, at least superficially, well recognized by horticulturists and refers to properties or characteristics that plant species have evolved in response to the demands of the habitats they occur in. Traits might be thought of as corresponding to a portion of a response gradient for all important environmental and biotic factors. If we think of light for example, it can occur from where photon density is very high in sunny places through to where it is very low. Few plants can grow and more importantly compete with other plants successfully across this whole range, and this is true of nearly every other climatic, edaphic and biotic factor that impinges upon plant growth. Other important traits involve the rate at which biomass is assembled, the position of growth points in relation to the soil, regeneration strategy and so on.

To design or assemble communities it is necessary to have an understanding of the key traits of the species in question. Returning to the example of the heavily shaded understory layer in a herbaceous plant community, what traits are required for the species in this layer to succeed and persist, and undertake the key role of preventing weed establishment?

A major requirement for base layer species is to tolerate very low light levels. There are a number of ways this can be achieved; by growing very slowly so as to require only low levels of photosynthesis and hence being able to maintain foliage for the entire 6-7 months underneath the taller layers of foliage. Not many temperate species can do this, but this trait is more common in the understory species associated with closed sub-tropical and tropical forests. More common in temperate species is the capacity to enter partial or complete summer dormancy when the light levels fall below compensation point. Some species which do either of the above, will emerge in spring, others will emerge in autumn, giving the latter a much longer season of leaf presence. These phenological traits are important not only for visual reasons but because they impact significantly on the capacity of ruderal species to establish in the community. The longer a ground layer foliage layer is intact the more capable a community is in terms of inhibiting weed invasion.

Other key traits in this situation might be the capacity of a species to perform at the soil moisture levels present. Species from high rainfall regions may simply be incapable of surviving severe moisture stress. Growth rate and plant morphology might also be critical, species that produce large amounts of biomass prior to the emergence of the taller species may inhibit or even kill these latter species. A balance must be found between the respective growth rates of the different layers. Shaded ground layer plantings in the moist climates of Western Europe are also constantly subject to high levels of slug and snail herbivory and relative unpalatability to these herbivores is an important trait.

One of the difficulties in assembling this trait information as a basis for decision making on plant community design and assembly is that the horticultural literature on plant traits is poor. There are a number of reasons why this is so. Firstly the horticulture concerned with public green struggles philosophically about whether it thinks in terms of preferences (the notion of the optimal) or in terms of tolerances (the notion of the suboptimal but good enough position). Most literature on plants is conceived from an optimal perspective. Many plants are killed in horticultural practice and in research when they are exposed to conditions beyond their range of tolerances but these observations-data rarely find their way to the literature. To allow plants to die in horticulture is often seen as a denial of the horticultural Hippocratic oath.

Death is however useful from an information perspective as it provides a guide to trait boundaries. Another reason why trait literature is poor is because in the absence of desire to run plants to destruction in practice/experimentation (and record the results), another way to gain similar understanding is to be familiar with the ecology of the plants in their wild habitats. If you can observe a species growing under dense canopy layers in nature, you can generally expect it to be able to do the same in designed plantings, all other things being equal. Most horticulturists do not however have this depth of understanding about plant behavior and distribution in nature. Rethinking the plant literature from an ecological and more specifically trait basis is a priority for 21st century Horticulture.

CONCLUSION

In addition to their intrinsic merits, plant communities, because they explicitly expose the component plants to inter-specific competition, present new, but much needed challenges to conventional horticultural thinking. Rather than see this as a threat, plant communities provide a vehicle to add a new strand of thinking, and most specifically to drive forward a re-assessment of horticultural information sources about plants. Horticulture has a key role to play in the twenty first century sustainable city from the strategic level of ideas through to implementation and management of the resulting vegetation. To be actively involved in the generation of ideas at a strategic level requires horticulture to update its understanding of the role of plants in designed urban environments.

Literature cited

Cardinale, B.J., Wright, J.P., Cadotte, M.W., Carroll, I.T., Hector, A., Srivastava, D.S., Loreau, M., and Weis, J.J. (2007). Impacts of plant diversity on biomass production increase through time because of species complementarity. *PNAS*, *104* (46), 18123-18125 http://doi: 10.1073/pnas.0709069104.

Darwin, C. (1859). On the Origin of Species (London, UK: John Murray), pp. 502.

Dunnet, N. and Hitchmough, J.D. (2004). The Dynamic Landscape, Design, Ecology and Management of naturalistic urban planting (London: SPON), pp. 332.

Grime, J.P. (1979). Plant Strategies and Vegetation Processes (Chichester, UK: John Wiley & Sons Ltd), pp. 222.

Grime, J.P. (2001) Plant Strategies and Vegetation Processes, and Ecosystem Properties (Chichester, UK: John Wiley & Sons Ltd), pp. 417.

Hansen, R., and Stahl, F. (1993). Perennials and their Garden Habitats (Oxford, UK: Oxford University Press), pp. 462.

Hitchmough, J.D., de la Fleur, M., and Findlay, C. (2004). Establishing North American Prairie vegetation in urban parks in northern England: 1. Effect of sowing season, sowing rate and soil type. Landscape and Urban Planning, *66*, 75-90 http://dx.doi.org/10.1016/S0169-2046(03)00096-3.

Hitchmough, J.D., and de la Fleur, M. (2006). Establishing North American prairie vegetation in urban parks in northern England: Effect of management and soil type on long-term community development. Landscape and Urban Planning, *78*, 386-397 http://dx.doi.org/10.1016/j.landurbplan.2005.11.005.

Nassauer, J.I., 1995. Messy ecosystems, orderly frames. Landscape Journal *14* (2), 161-170 http://dx.doi.org/10.3368/lj.14.2.161.

O'Brien, D.T. (2012). The Relative Influence of Individual and Social Incentives on the Treatment of Public Space. Human Nature, *23* (4), 467-489 http://dx.doi.org/10.1007/s12110-012-9156-6.

Özgüner, H., and Kendle, A.D. (2006). Public attitudes towards naturalistic versus designed landscapes in the city of Sheffield (UK). Landscape and Urban Planning, *74* (2), 139-157 http://dx.doi.org/10.1016/j.landurbplan.2004.10.003.

Rajan-Koppler, M., and Hitchmough, J.D. (2015). Ecology good, Aut-Ecology better; Improving the sustainability of designed plantings. JoLA *2* (15), 44-53 http://dx.doi.org/10.1080/18626033.2015.1058578.

Robinson, W. (1870). The Wild Garden (London, UK: John Murray), pp. 236.

Sheail, J. (1987) Seventy-Five years in Ecology: The British Ecological Society (Oxford, UK: Blackwell Scientific Publications), pp. 301.

Silva, E.M., and Dean, W.B. (2000). Effect of nectar composition and nectar concentration on honey bee (Hymenoptera: Apidae) visitations to hybrid onion flowers. Journal of Economic Entomology, *93* (4), 1216-1221 http://dx.doi.org/10.1603/0022-0493-93.4.1216.

Smith, R.M., Warren, P.H., Thompson, K., Gaston, K.J. (2006). Urban domestic gardens (VI): environmental correlates of invertebrate species richness*.* Biodiversity and Conservation *15*, 2415-2438 http://dx.doi.org/10.1007/s10531-004-5014-0.

Tansley, A.G. (1911). Types of British Vegetation, (Cambridge: Cambridge University Press), pp. 252.

Warming, E. (1895). Plantesamfund: Grundtræk af den økologiske plantegeografi (Kopenhag: Philipsens Forlag), pp. 335.

Weiner, J. (1998). Mechanisms determining the degree of size asymmetry in competition among plants. Oecologia *113*, 44-455 http://dx.doi.org/10.1007/s004420050397.