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SECONDARY SUCCESSION IN ABANDONED CROP FALLOWS: A REVIEW

Hom N Pathak
Prithvi Narayan Campus, TU, Nepal
Corresponding author: homnpathak@gmail.com

Abstract

The succession in areas once vegetated before the disturbance to a forest as climax community is called secondary succession. Secondary succession is influenced by soil type and the vegetation that invades the community. During the literature survey we found that the cropping areas are abandoned in different parts of the world and the fallows left are under secondary succession. There the socio-economy of the people has been found to affect the succession. Species diversity, species richness, rate of replacement and the soil type etc. have been studied by succession researchers. Succession study has also been carried out by using the tools like remote sensing, geographical information system etc.

Key words: Secondary succession, Goth system, Fallows

Introduction

Directional and cumulative change of vegetation in a community till the climax community is called succession. Succession may be the primary if the community change occurs in the previously non vegetated area. However, secondary succession occurs in once vegetated area after the disturbance due to climatic, environmental or anthropogenic causes.

In recent past, there was *Goth* system in hilly areas of Nepal. In *Goth* system *Gothalas* used to live in high hills domesticating buffaloes and other cattle. They used to rare buffaloes. They usually do not need to take extra care of the cattle as these cattle are used to move freely and graze nearby natural forests. When the cattle become matured and pregnant, the buffaloes were brought to the huts or *Goths* and sold at high price. In recent years, the *Goth* system is declining and the areas for *Goths* have been abandoned due to socio economic changes in life of the *Gothalas* and their families although very few *Goths* are seen in Bhadaure-Tamagi VDC of Panchase, Kaski. This review has been prepared in connection with the study of secondary succession in abandoned fallows of *Goth* practice in Bhanjyang of Bhadaure-Tamagi VDC, Panchase.

Ecosystems are dynamic. Disturbances lead to changes in ecosystems, collectively called succession. Disturbances can be natural and/or anthropogenic (human-caused). Natural disturbances, such as wildfire, play an important role in forest succession. Knowledge of natural disturbance regimes is important to maintaining biodiversity. In forest succession, species composition, ecosystem structure (Biotic and abiotic factors) and ecosystem functioning (Food chain and food web, energy flow) all change gradually over time. In urban areas, the alterations of natural disturbance regimes, along with the introduction of invasive species have altered natural succession. Natural disturbances vary in spatial scale (from small to large areas) and temporal scale (from hours to eons). Variation in the temporal and spatial scales of disturbances leads to ecosystems spread over the landscape that are in different successional stages. This landscape diversity meets the needs of a variety of wildlife species (Binelli et al., 2008).

Abandonment of cropping and succession

According to Cuesta *et al*. (2012) agricultural fallows, village commons and degraded forests, serve as important common community property resources throughout India, but due to their degraded status they are considered as 'wastelands', having little economic value and poor biodiversity. A study on secondary succession was conducted in agricultural fallows around Pundicherry, India to review the negative image of 'wastelands'. Chronosequences of four sites aged 2, 4, 10 and 50 years were used to investigate change in species composition and abundance, convergence with a nearby forest and to examine their economic use.

Large extents of abandoned fallows may undergo secondary succession or reforestation. Researchers experimentally tested the response of soil chemical properties to secondary succession (old field) and to *Quercus ilex* plantation (reforested cropland) in a Mediterranean cropland that was abandoned 13 years ago. They also evaluated the relevance of previous reforestation management (four combinations of presence and absence of irrigation and shading) in addition to current environmental conditions (herbaceous community and cover of oak canopy) on soil chemistry in the reforested cropland. Carbon and NH_4^+-N concentrations and availability of mineral N were higher in the reforested cropland than in the old field. However, soil pH, total N, P, K and NO_3^--N concentrations, mineralization rates, and available PO_4^{3-}-P were similar in the reforested cropland as well as in the old field. Previous reforestation management practices, particularly irrigation, and current environmental conditions, mostly biomass and composition of the herbaceous community, affected soil chemistry. Irrigation increased K and P concentrations and NH_4^+-N availability. This study highlights the overall slow dynamics of soil chemistry in Mediterranean ecosystems, which has resulted in little variation of soil properties in reforested cropland after more than a decade.

Vegetation succession plays an important role in soil restoration through accumulation of vegetation biomass and improved soil plant interaction (Lu et al., 2002). The researchers had linked Amazonian secondary succession forest growth to soil properties. In their studies in

three successional sites, pH value found decreased with fallow age, potassium found decreased, aluminum increased and nitrogen as well as organic matter also decreased.

Study by Liu and Huang (2005) reported that nitrogen and potassium increased in an order but pH increased because the shrub grassland was succeeded to coniferous forest to evergreen broad leaved forest. Thus pH seems increasing with fallow age and N, P, K found decreasing with fallow age.

Succession to naturalized grassland from former agricultural land and pastures is accompanied by changes in plant biodiversity and in the soil community. These changes are the result of a reduction or elimination of management, fertilizer applications and of grazing by large herbivores. Researchers reviewed soil biology studies on agricultural land that are in various successional stages towards naturalized grasslands, where interactions between plant species composition changes and the soil ecology affect each other. In many chronosequence studies, the soil microbial community tends to shift towards a less bacterial, and more fungal dominated food web energy channel following a reduction in fertilizer inputs and grazing intensity (Maharning et al., 2009).

In 1982, experimental nitrogen gradients were established on both existing and disturbed (disked) vegetation in three fields (abandoned 14, 25, and 48 yrs) and on existing vegetation in native oak savannah. Each of these seven gradients contained five or six replicates of each of nine treatments that differed in the annual rate of nitrogen addition. In none of the fields did plant biomass, height, species richness, or light penetration respond to addition of P, K, Ca, Mg, S, and trace metals. In contrast, plant biomass and height increased significantly, and light penetration and species richness decreased significantly, with added nitrogen along all seven gradients. In general, early successional annuals and short-lived perennials and plants of short stature at maturity reached their peak abundance in low-nitrogen plots, whereas plots, receiving high rates of nitrogen addition were dominated by long-lived herbaceous and woody species that are taller at maturity (Tilman,1987)

Species diversity and community composition in fallows under secondary succession

Species diversity and community composition were studied at 23 sites on similar western hemlock/Douglas-fir forest habitats, in undisturbed old-growth stands and stands at 2, 5, 10,

15, 20, 30, and 40 years after clear cutting, broadcast burning, and planting with Douglas-fir. Vegetation was sampled with three 5 x 60 m transects at each site. Invading herbs, then invading and residual shrubs, and finally conifers dominated through the first 30 years. Species diversity trends increased with diversity, peaking at 15 years and richness at 15 years itself. This initially high diversity (higher than that of old-growth stands) is short-lived. After the tree canopy closes, species diversity declines reaching its lowest values at 40 years (Schoonmaker and McKee, 1988).

Haripal and Shahoo (2010) examined the vegetational succession and quantitative community characteristics in some abandoned agricultural ecosystems of western part of Orissa, India. The phytosociological attributes in different abandoned rice fields were studied by taking quadrats of suitable sizes (1 × 1, 5 × 5 and 10 × 10 m^2 for herbaceous grass and nongrass, shrubs and tree species respectively). Quantitative community characteristics like frequency, abundance, density of different plant species, diversity and dominance index were examined. Importance Value Index (IVI) was calculated to understand the importance of individual species in a community. The distribution patterns of different species were analyzed by species sequence curve method. Finding showed that there is decrease in the number of grass stands and increase in the non-grass stands with the increase in the year of fallow periods. The study also indicated an increasing trend of species richness, abundance and diversity with increasing year of abandonment indicating the growth of secondary succession in this region.

Vegetation structure and floristic composition of a 15- yr - old secondary forest in an abandoned *Eucalyptus tereticornis* plantation of the Western Ghats (Peninsular India) was analyzed specifically. The current suite of species includes many with light weight, wind dispersed seeds and a mix of shade tolerant and intolerant species. The abundance of evergreen heliophytes with deciduous species suggests eventual development into a semi evergreen forest type. The present state of the stand may be characterized as a "pre-equilibrium" stage in forest development (George et al., 1993).

In a comparison of life-forms, species richness and diversity indices by Kinhal and Parthasaraathi (2008) showed that herbaceous species dominated up to 10th year sere, from

which point in succession, woody species became more common. It was in the 50th year sere that shrubs and secondary tree species occurring in nucleated clumps became dominant.

Thus studies showed that secondary succession begins with herbaceous species. Herbaceous community is replaced by shrub community and then by tree species ultimately. The species richness and diversity increases but is greatest at the secondary community.

Uhl et al. (1988) had studied vegetation composition, structure and biomass accumulation on thirteen forest sites that had been cut and burnt, used as cattle pasture, and then abandoned in the eastern Amazon near Paragominas, Para, Brazil. These Amazon ecosystems generally can recover after large-scale pasture disturbances. Only where land has been used too intensively for long periods, is reforestation uncertain, but probably less than 10% of the pasture land in northern Para has degraded to this level. Nevertheless, the re-growth forest, regardless of pasture-use history, will not necessarily have the same characteristics of physiognomy or species composition as that originally occupying the site. Moreover, as burning becomes more prevalent in eastern Amazonia, abandoned sites may not develop into forest and the irreversible degradation of the entire regional ecosystem must be contemplated.

Thus pasture development seems essential for reforestation and increase in biomass and secondary succession.

Drivers of the succession

Climate change is widely expected to induce large shifts in the geographic distribution of plant communities, but early successional ecosystems may be less sensitive to broad-scale climatic trends because they are driven by interactions between species that are only indirectly related to temperature and rainfall. Building on a biogeographic analysis of secondary succession rates across the Eastern Deciduous Forest (EDF) of North America, an experimental study designed to quantify the relative extent to which climate, soil properties, and geographic species pools drive variation in woody colonization rates of old fields across the EDF. Using a network of five sites of different soil fertility along a latitudinal gradient from central New York to northern Florida, there added seeds of nine woody pioneer species

to recently tilled old fields and monitored first-year growth and survivorship. Results suggested seedlings of southern woody pioneer species are better able to quickly establish in fields after abandonment, regardless of climate regime. Sites of lower soil fertility also exhibited faster rates of seedling growth, likely due to the slower development of the successional herbaceous community (Fridley and Weight, 2011).

Thus climate change has insignificant effect on early secondary succession because it is driven by species interaction and indirectly related with temperature and rainfall.

The composition and density of seeds in soils of secondary forests derived on abandoned fields after 4, 9 and 14 years of abandonment were enumerated to examine whether the soil seed bank assembles during secondary succession as the plant communities assemble. A total of 18, 37 and 48 soil samples from 4-, 9- and 14-year old sites, respectively were collected in 15 cm × 15 cm plots up to 9 cm depth. A total of 3, 5 and 9 species were found on sites abandoned 4, 9 and 14 years ago, respectively. Among different life forms, trees were highly represented in the soil seed bank of 9-year (60%) and 14-year (33%) old sites compared to 4-year old site entirely dominated by non-woody flora. The total number of seeds ranged from 327 in the 4-year old site to 146 in the 14-year old site, and the corresponding density of viable seeds ranged from 141 seeds $\cdot m^{-2}$ in the 4-year old site to 26 seeds m^{-2} in the 14-year old site with a consistent decreasing pattern in the chronosequence. The similarity between the soil seed flora and the standing woody vegetation was low for both 9- and 14-year old sites while complete dissimilarity was found for 4-year old site. It was concluded that the species composition of soil seed banks assemble gradually during secondary succession, but the overall seed density is still low for natural regeneration of trees to rely on. To expedite the recovery of secondary forests on such abandoned fields, the seed bank needs to be supplemented by direct seeding, enrichment planting of desired species and installing artificial perches for facilitating seed dispersal (Gonzalez-Rivas et al., 2009).

Thus seed deposition in soil and subsequent regeneration decreases with fallow ages but movement and establishment of propagules and seed transfer affects succession.

Analytical tools in succession study

A survey on plant communities by Alard et al. (2005) was performed with similar design for each site. Multivariate analyses were performed to study the relationships between vegetation and environmental variables so as to interpret the present vegetation variability. Co-inertia analyses show that, in both sites, (1) secondary succession dominates the general pattern of composition gradients in plant communities and (2) succession gradient is strongly connected with soil depth.

Researchers tested the biomass ratio hypothesis, which postulates that ecosystem properties should depend on species traits and on species contribution to the total biomass of the community, in a successional sere following vineyard abandonment in the Mediterranean region of France. Ecosystem-specific net primary productivity, litter decomposition rate, and total soil carbon and nitrogen varied significantly with field age, and correlated with community-aggregated (i.e., weighed according to the relative abundance of species) functional leaf traits. The three easily measurable traits tested, specific leaf area, leaf dry matter content, and nitrogen concentration, provide a simple means to scale up from organ to ecosystem functioning in complex plant communities. Researchers propose that they may be called "functional markers," and be used to assess the impacts of community changes on ecosystem properties induced, in particular, by global change drivers (Erich *et al.*, 1919).

The secondary forest succession was generated and mapped using a geographic information system (GIS) and remote sensing (RS), along with aerial photographs. Results show that anthropogenic disturbances and harvesting techniques have been the major causes of the succession. Under a selective harvesting regime, the trees left uncut or damaged would become the main components of the subsequent forest succession. The spatial database offers excellent opportunities to understand the vegetation dynamics and to help the forest manager in deciding future forest conditions for maintaining biodiversity (Cakir et al., 2009).

Conclusion

Disturbance and then succession provide the necessary nutrients to the growing inhabitants of the forest. Secondary succession brings about in an ecosystem or community where species richness goes on increasing, and biomass undergoes increasing with slight increase of older

fallows. The species diversity also increases gradually. Similarly, there is dominance of the herbaceous species in early year fallows become dominant and herbs are usually replaced by shrubs and subsequently by trees. Generally, there appears increasing trend of species richness, abundance and diversity with increasing year of abandonment.

The nutrient dynamics also shows the definite pattern in successive fallow communities. Thus pH and Al seems increasing with fallow age and N, P, K and humus found decreasing with fallow age.

Seed deposition in soil and subsequent regeneration decreases with fallow ages but movement and establishment of propagules and seed transfer affects succession. Climate change has insignificant effect on early secondary succession because it is driven by species interaction and indirectly related with temperature and rainfall. Pasture development seems essential for reforestation and increase in biomass and secondary succession.

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References

Alard, D., Chabrerie, O.T., Roche, P. and Langlois, E., 2005. Patterns of secondary succession in calcareous grasslands: Can we distinguish the influence of former land uses from present vegetation data? *Basic and Applied Ecology* 6(2):161–173.

Binelli, E.K., Gholz, H.L. and Duryea, M.L., 2008. Plant succession and disturbances in the urban forest ecosystem. University of Florida, IFAS Extension, FOR 93.

Cakir, G., Sivrikaya, F., Terzioglu, S., Bafikant, E.Z., Sonmez, T. and Yalosigmaz, H.A., 2007. Mapping secondary forest succession with geographic information systems: A case study from Bulanikdere, Kirklareli, Turkey. *Turk J Agric For* 31:71-81.

Cuesta, B., Rey Benayas, J.M., Villar-Salvador, P., González-Espinosa, M., 2012. Soil chemical properties in abandoned Mediterranean cropland after succession and oak reforestation, *Acta Oecologica*, 38:58–65.

Fridley, J.D. and Wright, J.P., 2012. Drivers of secondary succession rates across temperate latitudes of the Eastern USA: climate, soils, and species pools. *Oecologia,* 168 (4):1069-1077.

Garnier, E., Cortez, J., Billès, G., Navas, M-L., Roumet, C., Debussche, M., Laurent,G., Alain Blanchard, A., Aubry, D., Bellmann,A., Neill, C and Jean-Patrick Toussaint, J-P., 2004. Plant functional markers capture ecosystem properties during secondary succession. *Ecology*.85:2630–2637. http://dx.doi.org/10.1890/03-0799.

George, S.J., Kumar, B.M. and Rajiv, G.R., 1993. Nature of secondary succession in the abandoned eucalyptus plantations of Neyar (Kerala) in Peninsular India. *Journal of Tropical Forest Science*, 5(3):372-386.

Gonzelez-Rivas, B., Tigabu, M., Castro-Marin, G. and Oden, P.C., 2009. Soil seed bank assembly following secondary succession on abandoned agricultural fields in Nicaragua. *Journal of Forestry Research*, 20(4):349-354.

Haripal, K. and Sahoo, S., 2011. Vegetational dynamics in some tropical abandoned rice fields in the western part of Orissa, India. *African Journal of Environmental Science and Technology*, 5(1):37 – 44. http://www.academicjournals.org/AJEST

Kinhal, V. and Parthasarathy, N., 2008. Secondary succession and resource use in tropical fallows: A case study from the Coromandel Coast of South India, *Land Degradation & Development*. 19(6): 649–662.

Liu, H. and Huang, J., 2005. Dynamics of Soil Properties under Secondary Succession Forest Communities in Mount Jinyun. *Ying Yong Sheng Tai Xue Bao* 16 (11):2041-6.

Lu, D., Mausel, P. and Moran, E., 2002. Linking Amazonian Secondary Succession Forest Growth to Soil Properties.*Land Degrad & Develop*. 13:331-343.

Maharning, A.R., Aaron, A.A.S. and Adl, S.M., 2009. Soil community changes during secondary succession to naturalized grasslands. *Applied Soil Ecology*. 41(2):137–147.

Schoonmaker,P. and McKee, A., 1988. Species composition and diversity during secondary succession of coniferous forests in the western cascade mountains of Oregon. *Forest Science*, 34(4):960-979.

Tilman, D., 1987. Secondary succession and the pattern of plant dominance along eperimental nitrogen gradients. *Ecological Monographs,* 57 (3).

Uhl, C., Buschbacher, R. and Serrao, E. A.S. 1988. Abandoned Pastures in Eastern Amazonia. I. Patterns of Plant Succession. *Journal of Ecology*. 76:663-681.