LAND USE, LAND COVER AND SOIL SCIENCES

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Summary

Land is one of our most precious assets, and its use is multi-faceted. It provides food and shelter, it stores and filters water, and it is a basis for urban and industrial development. Land is, however, finite in extent. The combination of population growth, limited expansion of arable land, and the growing need for land for non-agricultural purposes, increases the pressure on – and competition for – the available space. In certain areas of the world available land per capita has reached a critical value of 0.15.

Land which is physically available is not necessarily accessible to those who want to use it. First, the land surface and its inherent production potential are under continuous threat due to a variety of natural degradation processes and human-induced (mis)management. Second, access to land is mainly determined by customary rules – ethnic and religious rules among them – and by land tenure regulations. Squatting and

other types of informal access occur in areas where the land tenure system is unclear, as is the case in parts of South America.

Land derives its interest from the vegetation and crops that can be grown on it. Land cover and land use are, however, dynamic, and are affected both by natural phenomena, such as climatic events and natural disasters, and by human activities, although the impact of the latter has mainly been felt in the more recent centuries. Generally speaking, arable land is extending at the expense of forest and pasture. Non-agricultural uses, including those for urban and industrial infrastructure, are continuously on the rise.

There is a close link between land use (and its inherent changes), access to land as affected by land tenure, and land value. The common thread that binds all these together is the fact that land is becoming scarce and desired, and that it has become an asset and a primary tool for income generation, wealth, and power. In other words, land has an exchange value and a price.

The gradual change from a rural to an urban society, in combination with the evolution from a concept of common ownership to one that is more individual, is reflected in the free-market economy, where land acquires value that is on a par with other tools of production. The value and the price of land are mainly determined by supply and demand, and by the underlying perception of the potential benefits that can be derived from the deal in question. There is a wide variety of valuation methods, focusing either on the inherent production potential and carrying capacity of land, or on its market value in a functional land market.

Concern about the growing competition for land by an increasing number of users, and the risk of further degradation of valuable land and biotopes, calls for a more rational and sustainable use of the available space. Land zoning and land use planning are therefore major issues for future decision-makers.

1. Introduction

The word “land” has many meanings. In *Webster’s Dictionary of the English Language* it applies to no less than ten subjects. Its common connotation is usually associated with a solid or specific part of the earth’s surface, a country, or a region, but land also stands for ground or soil, and for their specific qualities and properties. It is also used to distinguish rural regions from urban districts.

Land is one of our most precious assets, and its use is multi-facetted. Land represents surface and space; it provides food, it filters and stores water; and it is a basis for urban and industrial development, leisure, and a wide range of social activities. Land also stands for property, and is a production factor because of the vegetation and crops that can be grown on it. It even embodies a number of non-material dimensions, such as homeland, place of ancestry, a basis for survival or wealth. It is also an object that is taxed and desired by governments and interest groups.

The world's land surface is finite in extent. Land is, moreover, constantly under threat of degradation, mainly as a result of intensive cropping, soil mining, and inadequate management, and of population pressure. Hence, agricultural outputs today have to procure food for twice as many people in the world as there were a generation ago, and in fifty years this is expected to be four times as many. The next generation is likely to see the highest population that the planet has ever experienced. This growing demand for food cannot be met indefinitely through intensification of crop production and biotechnological progress; it also requires the extension of arable land. The overall result is an increasing competition for land.

A commodity that becomes in short supply, that is desired, and for which different users are competing, acquires value. The more the competition for available land grows, the more its value increases.

2. Land Cover and Land Use

Under natural conditions the interaction between atmosphere, hydrosphere, and lithosphere results in the formation of a loose soil surface on which a natural vegetation develops. This contact layer at the earth's surface defines what is commonly called "soil" or "land."

Soil refers to the loose upper part of the weathering zone at the interface between the lithosphere and the biosphere. It constitutes the rooting zone for plants. The nature and properties of soils vary as a function of the type of parent rock, and of climate. It is rare for the land surface to remain bare and uncovered. This is the case under circumstances where the soil is too shallow and either chemically or physically too poor to allow plants to grow. Most often, the soil provides enough rooting depth, moisture, and nutrients for a plant cover to develop.

Land has a somewhat broader meaning than soil. It too involves the natural resource attributes occurring at the earth's surface but, unlike soils, it incorporates the wide range of environmental conditions and processes which, directly or indirectly, are related to those attributes. A technical and commonly accepted definition of land, as given by the UN's Food and Agriculture Organization, is:

an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

(FAO, 1976)

The land cover defines the biophysical state of the earth's surface and immediate subsurface, thus embracing the soil material, vegetation, and water status. Originally, the term had a narrower meaning, and referred only to the type of vegetation that covered the land surface, but this concept was later broadened to include soils and biodiversity as well.

The natural land cover is generally a good expression of the soil and vegetation pattern that goes with the natural environment. Hence in the humid tropics, where high temperatures and ample moisture are present throughout the year, soils are deep, highly weathered, and often devoid of major nutrients, and the corresponding vegetation tends to be dense tropical forest. In the subtropics, with an alternate dry and wet season, soil weathering is less intense; the profile is less deep, and still holds a good number of weatherable minerals in the root zone; the vegetation is moderately dense and includes many drought-resistant grasses and xerophytic trees. Towards the higher latitudes, soil materials are less developed, and the natural vegetation holds more and more cold-resistant perennials or seasonal plants, which develop only in the warmer summer period.

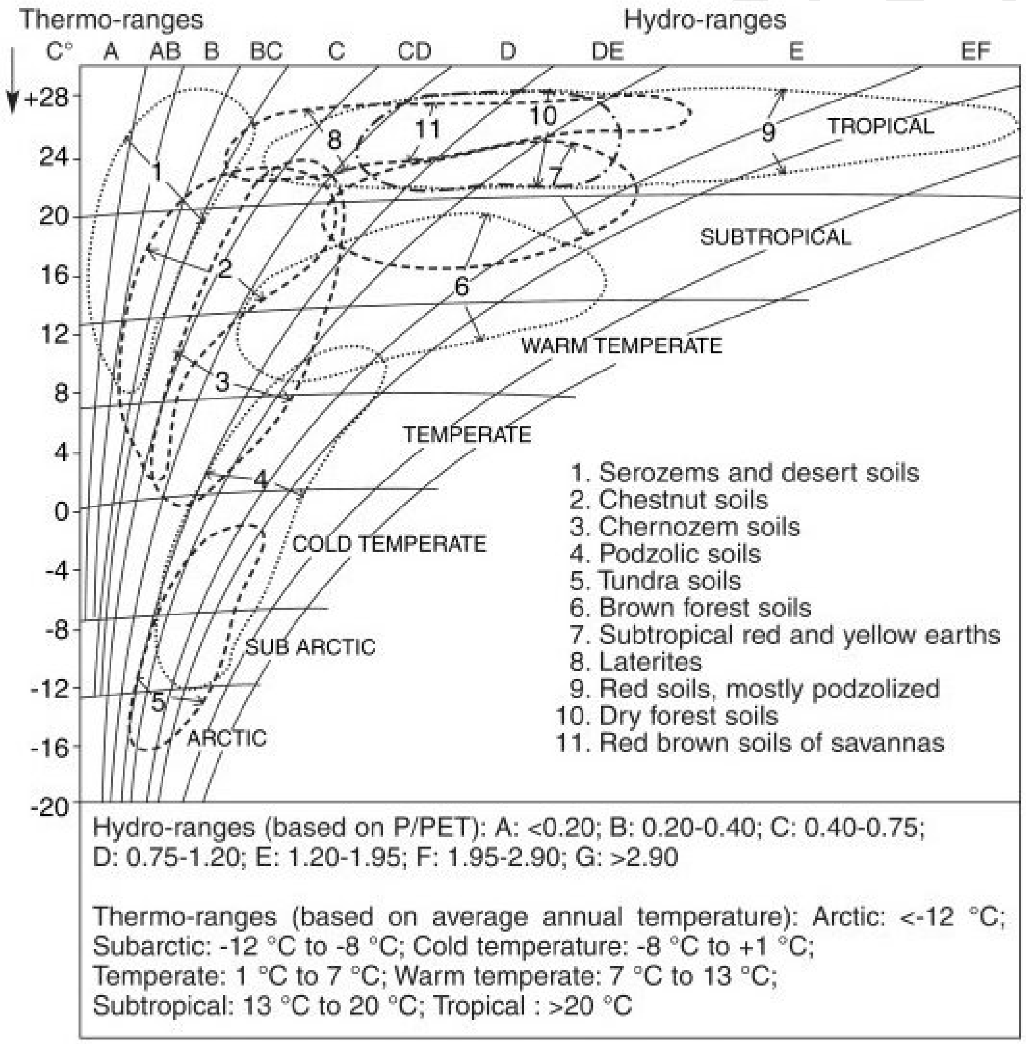

Figure 1. Distribution of major world soil groups in relation to climate (Voloboyev, 1956).

The close relationship between the natural land cover, in terms of soil and vegetation, and global bioclimatical zones was first studied and identified by Russian and German geographers. Voloboyev correlated dominant zonal soil types with thermo- and hydro-ranges (Figure 1), while Trewartha's work made it possible to integrate soil type and weathering zones with vegetation and bio-climatological areas at world level (Figure 2). In Voloboyev's system (Figure 1) the world is subdivided into eleven major soil zones, closely related to the natural vegetation they carry. These zones range from Serozems and Desert Soils in the drier areas, to Tundra Soils in the arctic regions, and Laterites and Red Brown Savanna Soils in the tropics. The extension of these soils follows a world zonal pattern determined by moisture supply and temperature/energy criteria, technically translated into hydro- and thermo-ranges respectively. Hydro-ranges are defined on the basis of the ratio of annual rainfall to evapo-transpiration, and are hence an expression of the plant-available moisture. Thermo-ranges are based on average annual temperatures with a direct impact on photosynthetic activity and related biomass production.

Zonal soils are interrupted at the regional level by so-called azonal and intra-zonal soil and vegetation types. These are linked to the appearance of site-specific features such as the presence of salts or alkalis in the soil and their related vegetation, the presence of marshland areas with a swamp vegetation, and so on.

Modern soil classifications like the FAO or USDA Soil Taxonomy systems nowadays put more emphasis on inherent soil properties, but have still maintained the underlying principle of world zonal differentiation, and the link with either the natural land cover or the land use potential for crop production.

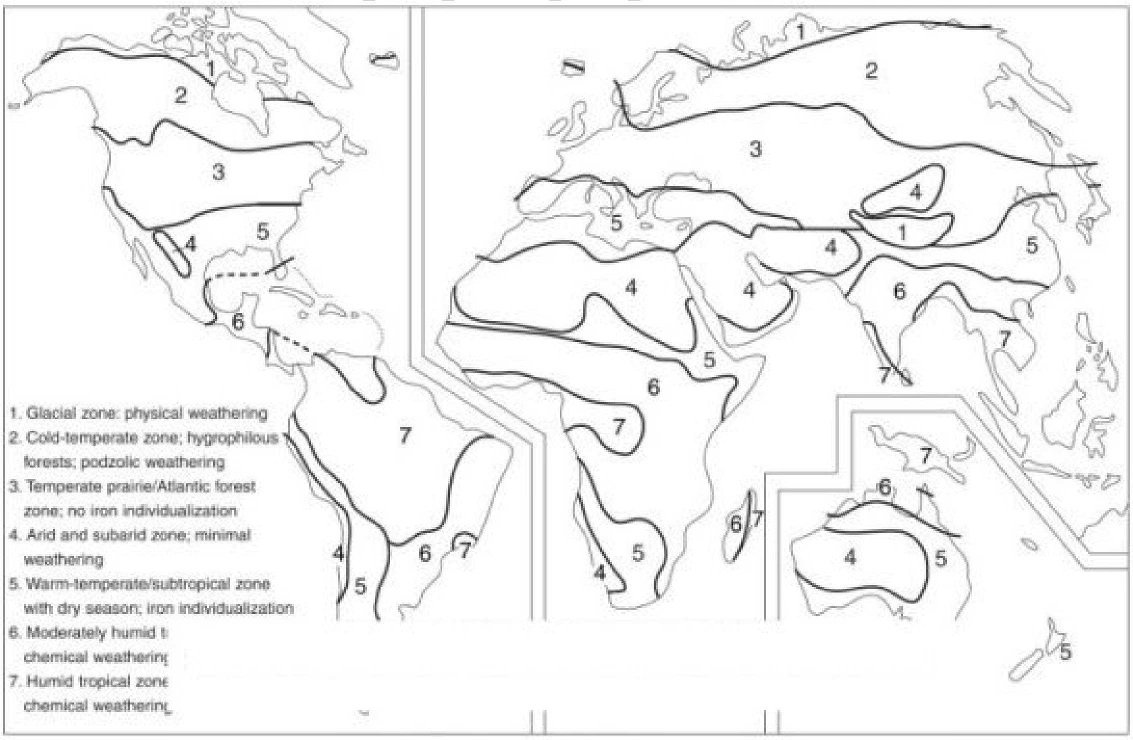

Figure 2. Major bio-climatological areas and soil weathering/major vegetation zones in the world (adapted from Trewartha, 1954).

The close relationship between bio-climatology and soil properties is illustrated in Figure 2, in which the world is subdivided into seven climate/vegetation/ soil weathering zones. In arctic areas (unit 1) water is chemically inactive, and soil/rock weathering is limited to a physical breakdown only. Unit 2 defines the cold-temperate zone with a hydrophilous (tundra) forest vegetation, creating an aggressive acid soil weathering environment, and the formation of podzolic soils. Unit 3 characterizes the temperate prairie and Atlantic forest zone, dominated by bi-siallitic soil weathering (formation of expanding clays), but without iron individualization (which means that soils do not turn red in color). Zone 4 stands for the arid and subarid regions where, due to the lack of water in the soil profile, both the vegetation and chemical weathering are limited. Zone 5 defines the warm-temperate and subtropical areas with intermediate dry season, including the Mediterranean zone, covered by (forested or grass) savannas, and dominated by a bi-siallitic weathering and iron individualization (which means that soils become red in color). Units 6 and 7 stand for the tropical wet and very wet areas covered by a dense tropical forest vegetation, and with a dominance of mono-siallitic (formation of kaolinite) or allitic (formation of kaolinite and toxic aluminum oxides) weathering respectively, with clear individualization and accumulation of iron.

Land use differs from land cover because of the intentional role of people to adapt the natural land cover to their benefit. The land use connotation entails an interference by humans and an underlying intention to turn the natural land resources into a beneficial output. It entails both the manner in which the biophysical attributes of the land are manipulated, and the intent underlying that manipulation, namely, the purpose for which the land is used.

According to the FAO concept, land use defines the human activities which are directly related to land, making use of its resources, or having an impact on them. In that context the emphasis is on the function or purpose for which the land is used, and particular reference is made to “the management of land to meet human needs.” The term includes both rural and urban or industrial uses. Land use automatically involves the concepts of optimizing the land use potential, land evaluation for example, and of land use planning. A distinction should be made here between present land use (the way in which the land is used at present) and potential land use (how it could be used with or without improvements).

Land use may vary in nature and in intensity according to both the purpose it serves – whether it be food production, recreation, or mining – and the biophysical characteristics of the land itself. Hence, land use is shaped under the influence of two types of driving forces: human needs, and natural environmental features and processes.
Land use and land cover are not equivalent. They may, however, overlap, and therefore be intermixed, because the distinction between the two is not always straightforward. The equivalence between natural pastoralism and unimproved grasslands is still clear, but it becomes vaguer when slight improvements in the grass cover have taken place. Likewise, it can be difficult to define the nature of forest exploitation if this takes place through a simple extraction of precious species from a natural forest (without further

disturbing the original structure of the forest), or when this happens through the integration of a small recreation or wildlife reserve within the natural forest.

The topic of land use and land cover has received ample attention in the international literature from Turner, Meyer, Moser, Briassoulis and others. The subject is also discussed *in extenso* in the contributions of Duhamel, Briassoulis, Klein-Goldewijk, Ramankutty, et al., in "*Land Cover, Land Use, and Global Change*".

3. Land Cover and Land Use Changes

Land use and land cover are dynamic**.** Changes may involve the nature (for instance, from a dense forest to a natural savannah, or to cropland) or intensity of change (for instance from a dense forest to either a temporary smallholder's field under slash-and-burn exploitation, or a permanent plantation), but may also include spatial (forest abatement at village level, or for a large-scale agro-industrial plant), and time aspects.

There are different reasons for land cover and land use changes. In the first place, they are the result of a large-scale disruption of the ecological equilibrium created by climatic changes or natural disasters such as sea-level rises, volcanic eruptions, or tectonic movements.

The presence of paleosols with obvious tropical characteristics in the South of Spain and Portugal is an indication of a former humid tropical climate at some time in the area. The famous cave drawings discovered in the Tassili and Hoggar mountains in the Sahara, picturing giraffes, elephants, palm trees, and other tropical features, are indicative of a climate that was definitely more humid at one time in this part of the world. Global climate change, though still very speculative, might have a similar large-scale effect.

Set alongside these natural changes in soil, land cover, and biological activity, which have been happening for billions of years, humankind's participation in these changes only dates back 10,000 years, and the last ten centuries in particular.

In studying the nature of land use changes, Briassoulis distinguishes between three major types of changes: land use/cover conversions, corresponding to changes from one type to another; land cover/use modifications, which refer to alterations in the structure or function without a wholesale change from one type to another; and the maintenance of the land in its current conditions against agents of change (Briassoulis, 2000). In the case of agricultural land use, the changes may include intensification, extensification, and marginalization.

Land use changes can move in two directions: either, in the negative sense, leading to land degradation and loss of (production) potential, or, in the positive sense, resulting in a higher value or potential. Land evaluation and land use planning are typical tools for optimizing the use of the land, based on its inherent potential, and a maximal tapping of that potential by the stakeholders. These aspects are discussed in more detail in Volume III *"Land Use Planning"*.

Land use/cover changes also involve the modification, either direct or indirect, of natural habitats and their impact on the ecology of the site. Biodiversity, in its broadest sense, relates to the richness of living forms under natural conditions or, in other words, the multidimensionality of the living world. In a stricter sense, biodiversity refers to the (genetic) variety of different species, the variability among organisms and individuals, and the variety in ecosystems.

Though the first studies of biodiversity hark back to Charles Darwin, it is only in the past twenty to thirty years that interest in biodiversity has revived. Initially it was mainly connected with the global loss of species, and with the appreciation of evolutionary aspects of biodiversity dynamics in relation to habitat conditions. Nowadays the focus is more on the loss of global biodiversity, and on the appreciation of the evolutionary aspects of its dynamics.

There is no consensus about the magnitude of the earth's biodiversity. About two million species have been described (not only through present-day observations but also as a result of paleontological research), but the real species' richness is undoubtedly much greater. The majority of extant species are concentrated in the tropics, and belong to a few phyla. Most of the species that have ever existed became extinct as a result of natural (namely, climatic or terrestrial) changes and disasters. Today the extinction of species is, however, largely the result of human activity, mainly related to land development, a process which has caused damage, habitat destruction, degradation, and fragmentation. Species restricted to isolated habitat fragments and reserves must rely either on their limited physiological tolerances, or on an evolutionary *in situ* adaptation.

Land use changes, and their impact on nature and on societies, may easily lead to competition and conflict situations. This competition may occur at different levels: for example, mutually between farmers or any other individuals; between poor peasants and landowners; between farmers and pastoralists for grazing lands and watering points; between farmers and foresters; competition for urban and industrial expansion in the peri-urban fringe at the expense of arable or forest land, etc. This is a dynamic phenomenon, and is closely associated with changes within the society and in land use patterns. In the worse case such competition leads to conflicts, land squatting, and violence.

In recent years a growing number of land conflicts have emerged that focus on the protection of the environment, and the preservation of biodiversity and wildlife. Through zoning regulations the limited land space can be used in a more rational way, and so-called green areas can be protected against land encroachment from expanding cities, or any other form of economically-inspired land development activities. Likewise, management restrictions can be imposed on agricultural land in order to avoid the further deterioration of the environment. Wise land-use policies require an enlightened balance between environmental concern and free market forces, leading to sensible restrictions on land use, for the benefit of society and future generations.

Land cover and land use changes can easily be monitored through remote sensing techniques. More details on this issue are given in *G. Eiden: Land Cover and Land Use Mapping"*.

4. Factors Affecting Land Cover and Land Use

4.1. Available Land

The total land area of the world is fixed, except for minor changes in the increase or decrease caused by coastal sedimentation, volcanic eruptions, earth-quakes, or sea level movements. The extension and production potential of cultivable land can nevertheless vary significantly: it can increase through drainage, land leveling, irrigation, and other human interventions, and it can decrease as a result of water and wind erosion, salinization, depletion of mineral nutrients, and reductions in biological activity. In analyzing statistical land data it is therefore important to define clearly what type of land area is meant.

A soil resource inventory carried out by FAO in the late 1980s has estimated that of the 13,340 million ha of the world's land surface that is free of permanent ice, only 3,030 million ha (23 percent) are potentially arable (FAO, 1991). The larger part of the world's soil cover is either too cold, too dry, too wet, too steep, too shallow, or too saline to support profitable cultivation (FAO Statistical Yearbooks, 1970–96).

The presently cultivated area in the world – arable land and permanent crops – is estimated at about 1,475 million ha (only half the potentially arable area); 3,200 million ha are under permanent pasture, and 4,050 million ha are forests and woodlands. Other land accounts for 4,615 million ha, of which 200 million ha are estimated to be covered by towns, roads, airports, industry, and other permanent infrastructure.

Of the 1,475 million ha of potentially available land, about 71 percent is in developing countries, and 29 percent in developed countries. That is about in the same proportions as the current world population. The major available land reserves, in absolute figures, are located in Asia and Africa (Table 1).

Year	Available land (in million ha)				
	World	Europe	Africa	Asia	S. Amer.
1965	1399	152	190	447	82
1970	1408	146	169	438	110
1980	1427	140	175	449	101
1990	1463	138	186	-	110
1991	1441	138	181	457	115
1992	1443	136	182	459	113
1993	1447	136	187	468	102

1994	1450	135	185	472	105
1995	1476	134	192	516	120

Table 1: Distribution of available land over the world (source: FAO Statistical Yearbooks, 1970-1996).

The picture is, however, completely different when the amount of effectively cultivated land is also taken into consideration. In the developing countries as a whole only 36 percent of the potential cultivable land is used, while developed countries currently use 77 percent of their potential arable land. There is also a great disparity between, for instance, Africa, where only 21 percent of the potentially arable land is used, and Southeast Asia, where the figure goes up to almost 92 percent.

The amount of effectively cultivated land in the world has almost stabilized at 1,475 million ha (Table 1). In Europe the arable land surface has even decreased, mainly because of urban development. Large reserves of land that is unexploited – due partly to harsh living conditions and partly to the migration of its former settlers – still exist in South America, and have recently been the target of international land speculators.

A further extension of cultivable land to meet the needs of a growing population remains possible, but will in the long term be restricted, due to physical constraints (too cold, too dry, too difficult for access, etc.), and poor living conditions. In addition, a further extension of cropping areas at the expense of natural areas will have to cope with environmental concerns, and with issues related to the protection of nature reserves and biodiversity. Land will therefore become scarce both from a mid-term and a long-term perspective.

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Biographical Sketch

Willy Verheye is an Emeritus Research Director at the National Science Foundation, Flanders, and a former Professor in the Geography Department, University of Ghent, Belgium. He holds an M.Sc. in Physical Geography (1961), a Ph.D. in soil science (1970), and a Post-Doctoral Degree in soil science and land use planning (1980).

He has been active for more than thirty-five years both in the academic world, as a professor/research director in soil science, land evaluation, and land use planning, and as a technical and scientific advisor for rural development projects, especially in developing countries. His research has mainly focused on the field characterization of soils and soils potentials, and on the integration of socio-economic and environmental aspects in rural land use planning. He has been a guest-professor in the universities of Algiers, Constantine, Tunis, and Morogoro (Tanzania). He was scientific coordinator for the post-university cyclus on Soils and the Environment at the University of Antwerp.

Willy Verheye has served as a technical and scientific advisor in more than 100 development projects for international (UNDP, FAO, World Bank, African and Asian Development Banks, etc.) and national agencies, as well as for development companies and NGOs active in the inter-tropical belt. He has organized various seminars on applied soil science and management aspects at the EU in Brussels, and has been guest or key-note speaker at many international fora. Under a UNDP-supported program he established the M.Sc. and Ph.D. programs in land resource management at Nagpur-Akola, India, and was elected a Fellow of the Indian Society for Land Use Planning for this work. He has also published more than 100 papers in international journals.

In recent years his activities have been mainly focused on participative planning methods in developing countries, with due attention both to optimization of production and sustainable land management.