THE CHOICE OF TREE SPECIES AS A STRATEGICAL CONCEPT

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Abstract

The choice of species is not a goal in itself, but a means to an end. It is a natural phenomenon and part of the management of a vulnerable ecosystem. It has to do with the plantation and the forest sensu-stricto and with all possible transitions between these fundamental types.
It has a double objective : the stability of the ecosystem and the continuity of its use, needing the acceptance of a dual strategy and a broad conceptual vision on forest use and forest care.
The choice of species is not unique and never definitive. It has to be done at several occasions and on different levels of forest development. It must acknowledge the multiple realities of change.
The choice must not be made between fast growth and slow growth, between tolerant and intolerant species, but aim at rightful use of species in adequate combinations of time sequences and space patterns.
Homogeneisation by choosing a single species should be the exception, because of the ecological and functional limitations.
The choice of species should be part of a coherent strategy recognising and respecting the natural strategies for colonisation, exploitation, adaptation, differentiation and conservation.

PLAN

1. THE CHOICE OF SPECIES

After colonisation of a new site by trees or whenever sufficient space is released and seed available at the right moment, a succession sets in. In its course early settlers are, in due time, relieved by better adapted species till a state of relative stability is attained (cfr. B r a u n, 1950 ; H u d s o n, 1957 ; B r a u n - B l a n q u e t, 1964 ; D a u b e n m i r e, 1968) through progressive control of the community over the physical environment.
The replacement of pioneers by more tolerant species with a greater life-span illustrates the transition of an exploitive to a more conservative natural strategy. It is characterised by decreasing entropy and a higher degree of homeostasis between the (forest) biocoenosis and its ecotope (O d u m, 1969 ; H o r n, 1974).

The forest is a relatively open system, dominated by long-lived trees increasing in height and biomass with the passing of time. Individual demands on space and energy increase simultaneously (V a n M i e - g r o e t, 1983), creating a new source of unrest and a continual change of the relations between species and individuals.

Furthermore, the forest, even in a stage of relative stability, is subject to perturbations, due to the release of internal pressure, the death of older dominants or caused by external influences.
Destructive external disturbances occur many times during the life-span of the dominant tree (M c B r i d e and L a v e n, 1976 ; H a s e, 1976 ; C o n n e l l and S l a t y e r, 1977), provoking complete or partial forest destruction on different space levels and with varying frequency. They cause modifications of site and environment with a loss of biotic regulation as a consequence.
To regain control and restore regulation, recolonisation of the site can follow different patterns and adopt different strategies. The nature of the new settlers and the subsequent succession of species roughly depends upon the amount of space and energy liberated by the perturbation.
Any kind of human intervention, direct or indirect, on a large or a small scale, accidental or wilfully executed following a well-considered plan, is to be interpreted as a perturbation of some kind. It sets the same processes in movement, provokes the same phenomena and has the same consequences as any other external disturbance. For this reason, the choice of species is the multidimensional and central problem of forestry and silviculture and not just a decision which species to use in afforestating fallow land or to reforestate clear-cut areas.
Even in these cases is to be reckoned with the impact of spontaneous settlements, previous, during or after afforestation. They tend to grow more important as wider spacing is used for planting and the quality of the site allows the establishment, in greater numbers, of a wider range of tree species.
If natural regeneration is used or mixed stands are artificially established, the choice of species is not restricted to the mere period during which the relief of generations is induced, promoted and executed.

As a matter of fact, the choice of species is not less important during repeated silvicultural interventions to regulate mixtures in established regenerations, laying the foundations for spatial distribution of species and developing the basic structural pattern of the stand.
Afterwards, it acquires a new dimension when, in thickets, the choice of species is linked to the selection of individuals in order to prepare the distribution of functions.
As soon as a certain degree of structural and functional stability is attained, the distribution of increment becomes the main problem.
In older stands, at last, regeneration is prepared, once again, by eliminating undesirable species and individuals, as well as by creating sufficient space for optimal crown development of mother trees, belonging to species, which management wishes to perpetuate.

The choice of species is a complex problem. Its solution requires a well considered line of thought. Not only from a theoretical, but also from a practical point of view, it is therefore advisable to base decisions on the knowledge and analysis of natural strategies, aiming at optimal forest stability and maximal control of the forest biocoenosis over the physical environment.

2. ELEMENTS OF A STRATEGICAL CONCEPT

Any attempt to work out a strategical concept must start with the definition of its object and the recognition of its principal aims. The way to realize acceptable aims must be indicated.
Strategical thinking in connection with the choice of tree species must further be based upon common denominators for different forest conditions.
It has to cover a sufficient period of time, as least as long as the normal life-span of dominant tree species. During this period social, political and economic situations are due to change continually.

2.1. The object

A wide range of motivations determine the wilful choice of tree species. It can be done at different levels and on various occasions.
It applies to all kinds of areas, covered or to be covered by tree growth, whatever its subsequent or ultimate use by man. It has to do with two fundamental ecological situations and all functional and structural transitions between these archetypes.

2.1.1. The plantation

The tree plantation is a highly homogeneized and simplified secondary or artificial ecosystem, created by man to obtain, as quick as possible, a maximal wood volume. It is fundamentally conditioned by human intervention and, quite often, temporary in character. It, nearly always, serves the interest of but a restricted section of human society.
The choice of species, applied to tree farming, plantations and thoroughly homogeneized forests, whatever their origin, is nearly always concentrated upon a single species, thought to be most promising and suitable for a very specific kind of use. The conditioning of the physical environment (soil preparation, fertilization a.o.) is undertaken to maintain a desirable level of production and use. To this end it tries to absorb the shock of disturbances, caused by exploitation at short interval and to gain control over the influence of the species on the site, especially the soil.
The plantation is monofunctional in its basic concept. Outside of wood production, all other functions are usually considered as secondary, unavoidable and even hindering. They are due to the physical presence of tree growth and, quite exceptionally, are the expression of wilful planning and management.
The choice of species goes nearly exclusively out from known or presumed growing results. The introduction, in homogeneous stands, of promising species from other regions and continents is frequently undertaken.
Great importance is given to their origin as well as to genetic selection, plant breeding and the chemical aspects of tree nutrition, as far as they affect growth and production. Due attention is given to resistance-breeding. Ecological analysis, including the impact of species, human intervention and exploitation is greatly neglected, or thought to be of minor importance.

2.1.2. The forest

The other archetype, commonly denominated as "forest", is extremely difficult to define. It comprise a broad range of formations, types and objectives for use.
The "forest" corresponds to a more complex ecosystem, in most cases deeply modified by human influences and often revealing characteristics, closely linked to a secondary type of succession.
Contrary to the plantation, where artificial reforestation after clear-cutting is the rule, the relief of one generation by another is done in the forest either by artificial or by natural regeneration, using a choice of patterns of distribution in space and time, that directly affect the attainable degree of forest stability and determine the morphological aspect of the forest.
Economic production is, by no means, a common denominator for all forests. In some cases wood production can be the principal, even exclusive aim of management, but in other forests it is given only restricted attention or not considered at all because other functions, rightfully, prevail.
In most natural or semi natural forests, even in a number of man-made forests, if not growing on marginal sites, several tree species grow next to each other : mixture, with a wide range of spatial and temporal patterns, is a frequent and normal phenomenon. The autochtonous element is nearly always present or has not completely disappeared, even if management concentrates on the introduction of foreign species.
The forest is multifunctional by definition, by its mere presence and by its basic bio-ecological characteristics. Actual and potential multifunctionality gets more attention as social, cultural, educational and ecological aspects of forest use are gradually becoming more important.

2.1.3. The product

In many cases wood production is no longer considered as the principal aim of forest management. Very often it is considered, and quite rightfully, as just a consequence of the presence of the forest. The growing importance, attached to forest conservation, functional stability and sustained value-yield in different forms, stresses the significance of the choice of species at all levels of intervention.

The confrontation of the two archetypes of a forested ecosystem leads to the conclusion that a strategy in connection with the choice of tree species must be directed toward or, at least, consider the organization of forest use in a broader sense. This does, however, not imply that the forested ecosystem itself should not be the principal object of such a strategy.

As a matter of fact, forest use can not be the object of a silvicultural strategy, because it is but an action, entirely dependent upon the existence of the forest in a certain form and stage of development.

The continuity of use is directly connected with the degree of stability of the natural, modified or artificial ecosystem. The quality of use is a reflection of the state and condition of the forested ecosys-

tem itself.
Therefore a dual strategy, simultaneously directed toward the forested ecosystem and its use, will be needed. It must be adaptable to the realities of change in time and space and in many fields, affecting the relationship between man and the forest.

2.2. The aims

The acceptance of a double aim in making the choice of species is unavoidable, but it complicates the problem.
It is evident that this choice must be linked, in the first place, to the object itself, the forested ecosystem, whatever its nature, with the intention to promote and guaranty its permanence, within acceptable limits of functional utility, at minimal cost and with the lowest possible input, directly and indirectly, of energy.
This partial aim answers the need for the creation and maintenance of a state of satisfying, if not optimal, stability. It is a permanent and unvariable goal basically independent from specific conditions of time and space.

Forest use, on the other hand, whatever its nature and importance, can not be but a secondary objective. It is subject to change under all conditions of time and space. It follows the acceleration of change in economic, social and cultural situations. The inherent variability of forest use does not affect its real importance, but it stresses the need for an unequivocal definition of its position.

2.2.1. Economic production

The direction of the choice of species towards any form of dominant or exclusive forest use nearly always increases the danger of destabilization of some kind and creates restrictions to the full use and development of other actual or potential functions.
Especially if short range economic and financial aspects of material production are given great preponderance, organized homogeneisation of the ecosystem and introduction of quick growing, mostly non-autochtonous species are prefered, dangerously threatening ecological stability.

The actual impact of "acid rain" on large tracts of the european forest and the dubious economic value of homogeneous pine stands, intended to serve pitprop-production, prove this point.
Therefore the economic and financial aspects of wood production must be carefully and objectively analyzed before making any decision.
The negative financial results of the german state forest are the object of common knowledge. In the Münich area the value of forest recreation, even assessed at an extremely low arbitrary level, surpasses many times the value of timber production (B i c h l m a i e r, 1970). Financial results are negative in an important part of the dutch forest, although important subventions are given (B e r g e r and V e l d h u y z e n, 1979 ; B e r g e r, 1982).

In Belgium the unequal evolution of production costs and wood-prices has created a most precarious situation. The total cost of afforestation has risen from 5.300 - 9.500 BF/ha in 1961 to 32.900 - 57.100 BF/ha in 1982 (index = 600 - 620). Wages of non-specialized forest workers increased, during the same period, from 200 BF/day to 1.670 BF/dag (index = 835), costs of plowing from 725 BF/ha to 7.000 BF/ha (index = 966) and the price for pine seed from 500 BF/kg to 5.500 BF/kg (index = 1100).
Over the same period wood prices were, evidently, also on the rise, but not quite so spectaculary.

For trees of diameter-class 50/60 cm. following mean prices were noticed (BF/m^3 for standing timber).

	Spruce	Beech	Oak
1958	942	768	1.046
1982	2.084	1 581	3.231
Index	221	206	309

It is evident that some aspects of wood production are marginal economic activities under certain conditions.
Mass-production is most indicated for countries with a large, low-cost labour reserve, a modest level of transportation costs, little competition for the use of productive space and great possibilities for mechanisation. In industrialized countries forest management better concentrates, to its own advantage, on the qualitative aspects of material production, meeting the need for measures to permeate the forest and accepting restrictions, arising from increasingly important social forest use.

In both case the choice of species should be made in function of the specific aims, restrictions accepted. Subsidiary, it becomes even more important in industrialized countries to make a clear distinction between forest and plantation, not only mentally, but also in connection with spatial distribution and allocation of space.
Both types should be allowed to develop as good as possible on the most appropriate sites.

2.2.2. Ecological stability

Whatever the options for forest use, controlable ecological stability of the forested ecosystem remains the principal obligation of forest management.
When deciding upon the choice of tree species, whatever the motivation, at each occasion and under all circumstances, an awareness should exist about possible repercusions of this decision on the system, particularly on its durability, resilience, stability and aptitude to absorb external shock. It is therefore necessary to explore the nature of stability and destabilization.

B o r m a n n and L i k e n s (1979) characterize bio-energetic stability by 3 basic conditions :

- Prevalence of biomass production over losses or, at least, egality between both.
- Control of the biocoenosis over the flow of nutrients and soil particles, resulting in control over erosion and energy output.
- Regulation of the hydrological cycle by transpiration and water storage.

The fulfilment of these conditions tends to promote the creation of a relative steady state, with restricted variation in species content and primary production (S p r u g e l, 1976). It has a sub-maximal level of biomass and primary production, as well as a high ratio of biomass to energy input (D r u r y and N i s b e t, 1973).

As such, optimal stability of a forested ecosystem can never be equated with maximal material production. If maximal wood production is aimed at, exploitation must necessarily be undertaken at the point where the curves for current and mean annual increment cross and well before physical maturity is reached (C o u s e n s, 1972 ; P a c k h a m and H a r d i n g, 1982).

2.2.3. The nature of the compromise

For all reasons, already cited, the alternative choice between optimal stability and maximal production has repercussions on the choice of species.

Maximal production over a restricted period of time is more easily obtained in a plantation-type of artificial ecosystem, using quick-growing species in homogeneous stands and adopting short rotations. The main problems in this case, the maintenance of stability and sustained yield, are met by trying to increase external control. But quick growth and short rotations must unavoidably result in repeated periods of reorganisation of the ecosystem, covering a large part of the rotation. Rotations, in turn, only exceptionally surpass the terminal phase of aggradation.

In the more complex forest-ecosystem, where mixture of species prevail, greater importance is given to ecological stability, accepting a submaximal level of biomass and material production, not to be equated with a low level of value-production. Slower growing species dominate ; rotations are longer or do not exist.
Although each silvicultural intervention includes an appropriate degree of external control, more importance is attached to the maintenance and promotion of the processes of self-regulation. Quick recovery of biotic control, if lost or diminished by intervention or external perturbation, becomes a preponderant objective of silvicultural management. To reduce the incidence of reorganization, the regeneration area is

spatially restricted, the forest soil not needlessly uncovered and species are chosen for their structural qualities and longer life-expectancy.

Although both systems are clearly different with regard to species content, structural patterns, sequences in time of developmental processes, level of biomass and production, degree of stability and aims of management they, nevertheless, grow and develop following the same fundamental laws.

They are equally subject to inputs of external energy such as radiation, wind, water and gravity with a high potential for destabilization (B o r m a n n and L i k e n s, 1979), which may, eventually, destroy the organization of the ecosystem or sweep away its substance. To survive and to grow, a forested ecosystem must be able to meet these potentially destabilizing forces. The core of each silvicultural decision, including the choice of species, must therefore be the awareness of the need to promote and help create an equilibrium between the forces of entropy and negentropy (O d u m, 1969, 1971), between the development of ecosystem organization and its rupture.

In this view, forest and plantation are not real opposites, but rather complementary. In both systems control is exerced in a different way, reflected in different patterns of development in time and space.

The need for continuity is, however, of fundamental importance in all managed ecosystems. It is connected with a corresponding steady-state, with different scales of time and space used for assessment. Such a steady state must not be equated with a state of invariability.

To promote continuity, two objectives prevail, with all consequences :

1° Maintenance of a certain level of biomass production and distribution, adaptable to changing needs in time and space.

2° Maintenance of biotic regulation within the forested ecosystem.

To achieve optimal biotic regulation, three groups of measures must be considered :

a. Restriction of the annual and individual regeneration area, in particular the clear-cutting area.
b. Elaboration of a good regeneration pattern, well-defined in time and space.
c. Adaptation of the choice of species to a compromise between the aims of management, ecological restrictions and the need for continuity.

It is evident that the central problem in use and management of a forested ecosystem resides in the choice of species. No single species is able to guaranty optimal and simultaneous fulfilmentof all rightfully required functions. All homogeneous forest ecosystems, whether by choice of management or as a consequence of environmental stress, are functionally desequilibrated.

2.3. The means

The choice of species is a means to an end and not the end in itself. In nature it serves the survival of a community with many dynamic features. In a forested system under management, the choice of species, directly or indirectly executed by man, must fundamentally aim at stability and continuity, widely taking human use of the forest into consideration.
As there is no unanimity over the aims of silviculture and forest management, the importance of stability and functionality is also viewed differently. Consequently, different standards are used to evaluate species and to decide upon their choice.

2.3.1. Early succession species

The level of ever increasing wood consumption and economic pressure have resulted into the acceptance of the need to accelerate wood production for fuel or as an industrial raw material. It is translated into a preference for fastgrowing tree species, to be cultivated under partially controled environmental conditions. Rate of growth, the level of current volume-increment and, up to some time ago, financial returns are adopted as "objective" standards, to judge a species. No particular importance is attached to forest stability, thought to be attainable by technical intervention. Management is directed toward short-range or intermediate-range objectives and conceived for a period of time, much shorter than the normal natural life-span of the species in use. To warrant maximal volumetric production and increment, exploitation is mostly undertaken no later than when C.A.I. reaches the level of M.A.I. Acting this way, artificial regeneration, mainly by planting, is unavoidable. A variety of clear-cutting systems were developed to this end, which have systematic ecological perturbation and ecosystem-reorganization within short intervals as common characteristics.

Such system must favour, nearly by definition, shade intolerant, early succession species with an indeterminate growth pattern (M a r k s, 1975) and a growth regime, corresponding to an exploitive strategy. Early succession species are, nearly always, impressive growers. They achieve extension of the vertical axis or leader over a large part of the growing season. By their morpho enetic characteristics, they do not tend to bifurcate, but have erect shoots (W h i t n e y, 1976). They produce new leaves and internodia as long as favourable environmental conditions during the growing season persist.

Quick growing species are well adapted to disturbed situations, but they weaken under highly competitive conditions. Compared to tolerant species, their root-shoot ratio is much lower (M a r k s, 1976), indicating a tendency to invest available energy in above ground structure and development. Their rooting is geared toward temporary occupancy of the site : roots are more concentrated in the forest floor, diminishing the mechanical stability of the tree, as well as its potential to help create collective stability.

Because quick growing species are able to use site abundance maximally and capitalize on any site enrichment, their extension growth is directly related to the conditions during the current growing season, making them highly vulnerable and their growth irregular.

The use, because of their quick growth, of early succession species or species with indeterminate growth to create forest stands or plantations, requires appropriate silvicultural technics, deducted from their growth characteristics :

- Creation of disturbance, to which they respond so well, by clearcutting and a preference for large regeneration units.
- Protection against competition by avoiding mixture and adopting short rotations.
- Artificial enrichment of the site to which species with indeterminate growth react quickly and positively.

The possibility to permeate such a system is doubtful. It requires an ever increasing input of energy. Management costs can quickly reach a level, where positive financial results are no longer expected.

Ecological stability is threatened and so is, in the end, the continuity of use.
The possibilities of genetic selection to produce ever faster growing individuals are limited. However, the acceleration of growth, if not the improvement of tree quality, seems precisely to be the means to meet rising costs, as well as resistance breeding must balance the shock of increasing external perturbation.

2.3.2. Late succession species

In search for an acceptable solution, study of natural succession teaches that, on most non-exclusive sites, the presence of intolerant pioneers is only temporary. In the course of succession they are relieved, in due time, by more tolerant species with a determinate growth pattern, which typifies the transition from an exploitive to a more conservative strategy.

The potential for stabilization of these late succession species is illustrated by their features :

- They have a higher root-shoot ratio and a root system geared for longtime occupancy of the site (M a r k s, 1975).
- Most photosynthates are used to support radiate and root growth or to restore energy reserves, rather than invested in extension of growth by elongation of the vertical axis (K o z l o w s k i and K e l l e r, 1966).

- Growth is regular ; it depends less on current environmental conditions ; extension growth draws on carbohydrates, stored during the previous growing season (K o z l o w s k i and K e l l e r, 1966 ; M a r k s, 1975).
- The number of leaves is determined during the previous season and senescence is concentrated in the last phase of the growing season. About 4 weeks before senescense, N- and P-concentrations within the leaves decrease and nutrients are transfered toward perennial portions of the tree to be stored during dormancy (R y a n, 1978).

Tolerant climax-species with determinate growth are well-suited, above others, to meet highly competitive situations. Largely using stored energy, they can exploit favourable environmental conditions at the beginning of the growing season when availability of nutrients is at maximum (M u l l e r and B o r m a n n, 1976 ; M e l i l l o, 1977) and water supplies are fully recharged (B o r m a n n and L i k e n s, 1979). They can use a wide range of light intensity.

Tolerant species with determinate growth are not suited to occupy large areas of disturbance, but they are highly competitive and, once established, take firm control over the site. By the investment of a large portion of available energy in root development and radiate growth, as well as by their slower juvenile growth and larger life-span, they promote ecosystem stability, provide optimal biotic regulation and have better control over the flow of water and nutrients in the soil.

From the point of view of silvicultural management, the characteristics and life expectancy of tolerant, late-succession species induce longer rotations, if any, seriously limiting the incidence of recurrent reorganization and aggradation.

Many combinations for regeneration can be considered, but regeneration under cover or in not too large groups, adopting long regeneration periods, are most advisable. Large areas of disturbance must be avoided. By their position in spontaneous or controled succession, tolerant species serve the creation and maintenance of mixed stands. By their structural and functional qualities, they help to reduce, in time and space, variations in growing stock, increment, species combinations and biological substance.

2.3.3. The combination of species

In last analysis it appears that the choice must not be made between fast and slow growing species, intolerance and tolerance, indeterminate and determinate growth. The choice resides in the rightful uses of species, conscious of their qualities and characteristics, in adequate combinations, adopting, to this end, gratifying time sequences and creating appropriate patterns of spatial distribution in order to obtain, simultaneously, satisfying results in several fields of human interest.

Fast-growing species must be used to meet catastrophic situations, following external perturbation and large scale internal degradation, or to quickly create a forest cover over large areas of release. Tolerant species, on the other hand, must provide stability and continuity.

It should be recognized that homogeneity is an exceptional situation. It severely restricts forest use and is connected with a lower level of biotic regulation and ecological control.

3. SYNTHESIS

The choice of species is not a goal in itself, but a means to an end. It is a natural phenomenon and part of the management of a vulnerable ecosystem, highly suitable to the production of material goods and the delivery of services, provided it is treated with circumspection.

The choice of species should be included in a broad conceptual vision on forest use and the care of forested ecosystems. Its direction toward shortrange economic and financial objectives, preponderantly concerned with quick wood production, limits the possibilities of choice and does not guaranty the stability of the system, even endangering the dominant type of use, it is supposed to serve.

The choice of species is not unique. It has to be done at several occassions and on several levels of forest development. On most non-exclusive sites a number of species can grow, either simultaneously or in succession, creating constantly evolving structural and functional combinations.

The choice of species should never be definitive. It must reckon with the multiple realities of change and consider the necessity of adaptation to ecological and environmental evolutions, as well as to the inevitable modifications in forest use, dictated by a society of consumers, subject to continual and accelerated reorientation.
The decision, with short-range and exclusive maximalization of wood production in mind, to limit the choice to a single species on sites where several species can grow and different combinations are realizable, impliesa number of secondary decisions, made or accepted simultaneously :

- to create and recreate a situation of disturbance in order to maintain the chosen species at the given site ;
- to use only part of the normal life span of the species, as exploitation must be undertaken as soon as current increment begins to drop ;
- to protect the species against competition by controling succession and opposing the natural strategy toward differentiation, which, however, works in favour of ecosystem stability ;

- to use stand treatment as a brake on the forces of self-regulation ;
- to accept and organize artificial control over environmental conditions.

The choice of species should be part of a coherent strategy, primarily conceived to protect and to maintain the system in a condition of optimal functionality. In second place, it is directed toward continual use, at a satisfying level, for different purposes, including wood production. Species must be judged upon their relationship to the site, their position in succession, their growth patterns and their role in the maintenance of biotic regulation. It is especially important to assess their specific durability and resilience under given conditions.

Particular attention should be paid to growth rhytms and to the fundamental differences between determinate and indeterminate growth, because of their repercussions on stability, regulation and production.

A coherent strategy for silvicultural management of a forested ecosystem, culminating in the choice of species at several occassions and on different levels, must go out from natural strategies, which it endeavours to incorporate :

- colonisation of a released space, especially in large areas of disturbance ;
- exploitation of an increased flux of energy ;
- adaptation to ever changing conditions, whether induced by external influences or resulting from internal stress ;
- differentiation to create, temporarily, the most stable structural and functional combination of species ;
- conservation to maintain the forest ecosystem in its full complexity, maybe at a sub-maximal level of biomass and material production, but in a state where stability and continuity of use are warranted.

Such a strategy, difficult to work out and still more difficult to apply, will, in the long run, produce maximal multiple profits to a demanding human society in continual change. It will also help to promote over-all ecological stability, so much in danger at the moment, due to the absence of a global vision on the impact of human interference with nature.

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