A New Attempt at an Ecological Classification of Land Utilization Systems

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The present article is a follow-up to a previous one (Christiansen, 1979). After a brief review of previous classifications, an approach will be advocated for an ecologically-based classification of utilization systems, consisting of two elements: one describing the productive environment (the 'econiche') to which utilization must be adapted, and the other describing the main ways by which the application of available plant nutrients and water are administered in an attempt to cope with these major constraints on productivity (the 'ecotype' of the utilization system). The main intervention is by concentrating nutrients and/or water by applying a variety of methods. An overall plan of the attempt is presented in a table at the end of this article.

Key words: *Agricultural systems, classifications.*

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PREVIOUS CLASSIFICATIONS

Early classifications of land-utilization systems were most often based on the idea that their classes shown in sequence should reflect stages of the systems, passing from primitive to advanced, and that one key characteristic would be enough to 'express the essence' of any one of these classes.

The classifications by Hahn (1892) and Werth (1922, 1954) demonstrate this line of thought very clearly and most scholarly. Both found that the main *implement* used in agriculture characterizes the system above anything else, and that the sequence 'grabstock', hacke und 'pflug' (digging stick, hoe and plough) reflects the mainstream of the development that historically took place. Similarly, the *cultivars* utilized, roots, small grains and 'coarse' cereals, in that order, were seen to reflect normal development just like the implements to which they were closely related.

Classification along the lines indicated remained unchallenged for long. Most observations based on systems operative during the turbulent days of early colonialism maintained that the criteria pointed to very distinctive differences in cultivation practices, and the growing archaeological evidence for the history of civilization largely supported these ideas. This is not to say, that improvements were not suggested. In the diagram depicting the path of development (fig. 1), Hahn argued for an

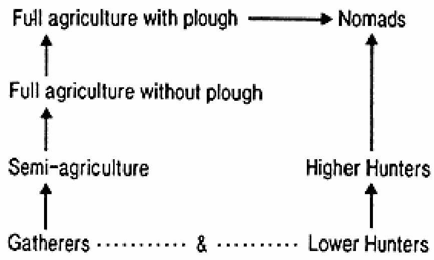

Fig. 1. Stages of development, based on Hahn (1892), modified by Hatt (1922).

origin of nomadism, not solely stemming from 'gatherers and lower hunters', as is usually put forward, but also having been influenced by agricultural people. The other major aspects, such as accepting 'gatherers' as the originators of 'hackbau' (hoe-cultivation), which was further developed into 'ackerbau ohne pflug' (agriculture without plough) and later to 'ackerbau mit pflug' (same with plough), were continuously sustained by Hahn.

Some Danish researchers, Hatt and Nicolaisen, also participated in the discussion. Hatt noted (1922), that reindeer-nomads ought not to be included in a general nomadic stage as proposed by Hahn's scheme, since their culture clearly revealed an origin related to (Nordic) agricultural societies, a connection that is not evident in the case of cattle nomadism. He also suggested an additional stage, that of 'semi-agriculture', more primitive than that of 'ackerbau ohne pflug', characterized by the use of a digging-stick or hoe and by the leading role played by women in production (fig. 2). The intention was to explain the transition from 'gatherers and lower hunters' to the stage of 'full agriculture without plough'. The argument was, that since the women of 'gatherers and lower hunters' mainly took care of the gathering of vegetable foodstuffs, they were most likely to be the inventors of early agriculture. In a way, Hatt inspired a series of classifications to be based on social characteristics, e.g. that of Bobek (1954), in spite of the fact that the role of females in semi-agriculture, assumed by Hatt, does not seem to be specifically theirs, and hence female participation is not a valid criterium for that class.

Nicolaisen (1963) further elaborated the arguments for a different background for the two types of nomadism; cattle- and reindeer nomadism.

The inspiration by the early German theoreticians gave rise to much speculation on how the transition from stage to stage took place, sometimes giving leads for later research by archaeologists and historians. A fine example is Carl Sauer's theorizing (Sauer, 1952) on the development of early (shifting) agriculture out of gatherer-hunter societies. At the same time, it gave an explanation for the

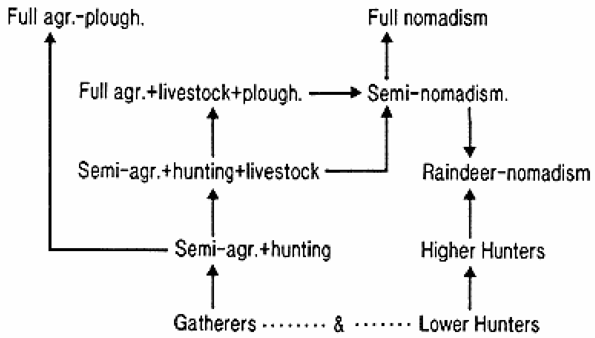

Fig. 2. Stages of development, based on Hatt (1922), modified by Nicolaisen (1963).

presence of (poisonous) roots among early cultivars, and the fact that these plants all belong to the category of 'invaders of clearings in forests'.

One of the later contributions to the series of genetical/monocriterial systems was that by the economist Boserup (1965). She used the intensity of land-use as the single criterion, like many geographers, such as H. Ruthenberg (Ruthenberg, 1971). Boserup also applied economic reasoning to develop a theory on the present situation in developing countries based on the historical evidence of changes. A scarcity of land (mainly stemming from population growth) forces people to intensify land-use, meaning more toil to produce the same amounts of food, unless work is substituted by animal traction or machinery. Boserup's work produced a lot of inspiration, since it gave a clear explanation for changes and also offered a basic theory for assessing 'development'.

Dissatisfaction with the genetic/monocriterial classifications had been expressed from time to time. Whittlesey (1938), in his classification, aimed at providing a practical tool for distinguishing contemporary 'types' of world agriculture, allowing its easy presentation in the form of a world map. By refraining from normal classified approaches (such as the use of independent criteria one at a time and for the whole population to be classified), he alternatively arrived at a relatively simple system that became much used. It was, however, criticized, by some theoreticians mainly because of its methodology, see e.g. Grigg (1974).

To overcome this difficulty, among others, an international group of geographers within the IGU, led by J. Kostrowicky, took the initiative to establish a modern classification, based on strict adherence to the rules of classification. Variables were suggested and selected by a circle of geographical colleagues. A broad set of parameters was finally agreed upon, spanning from structural, social, economic and performance-oriented ones to others quantifying the various production inputs (Kostrowicky, 1976). Since most of the parameters were quantitatively expressed, they were standardized to a five-step scale, arranged in groups, and depicted in a circular typogram (fig. 3). The typogram is useful for comparisons, both of different systems and of the different stages of development within the same one. As all axes have the same orientation in the typogram, it can be said, in general, that the more a figure connecting points on the axes fills the circle, the more 'developed' the depicted system is. The concept is a little blurred due to the fact, that the level of development is, in some cases, perceived and expressed rather arbitrarily. For example, is socialist agriculture more developed than capitalist?

The data used in the exercise was later subject to a classified procedure to reveal the 'relationship' between the various types of agriculture. To some degree, the traditional classes or 'stages' were reproduced by this method. No doubt, this is due to the fact, that some of the key-criteria used in the traditional classifications have strong correlations to many of the additional ones used by Kostrowicki.

Especially for geographers who want to study the relationship between man and the environment, the classifications mentioned leave a lot to be desired. The structure and performance of any land utilization system must be seen against a background of the productive potential of its environment. Hence, *any viable type of land utilization reflects both a (passive) adaptation to its physical environment and an (active) adaptation of given technical and economic means applied to overcome local constraints.*

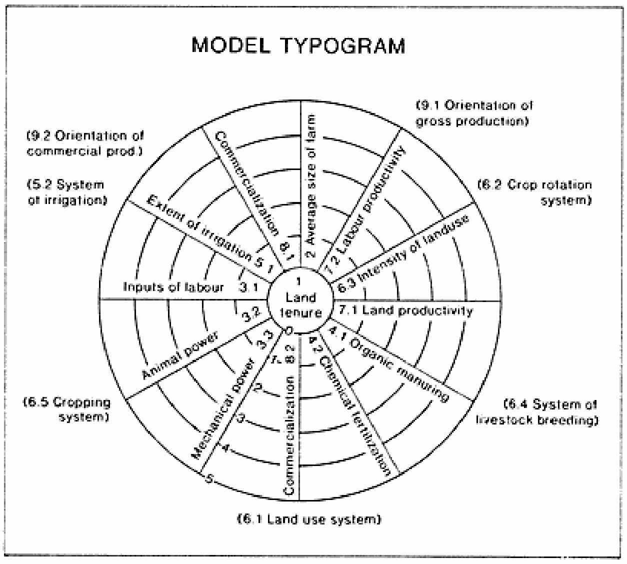

Fig. 3. Typogram for the characterization of agriculture by Kostrowicki (1975).

Within the disciplinary realm of 'Geography', attempts to describe the physical environment in relation to possibilities for food production have been made from the earliest days. Main thrusts have been at descriptions of (agro-)climate, soil fertility, 'land capability', 'ecological zoning', 'potential plant productivity' or similar, even more complex, expressions.

In the early classifications of climate, distinctions that aim at expressing the suitability of a region for agriculture were often derived from observations of the most indicative natural vegetation. This is the case of the classification by Köppen (1923) and, more expressly, the much less known system by Vahl (1922). The last one was based on criteria found in the botanist Raunkjær's work on 'vegetative life-forms' (Raunkjær, 1907), yet its zonation was defined on the basis of the distribution of selected and important cultivated plants. Whereas Köppen and his followers steadily refined his system, Vahl's more logically founded system remained unimproved and little known. It was published in Danish only. Lately, updated Vahl/Raunkjær ideas have been utilized in new attempts at reforming biogeography e.g. by Dansereau (1957).

Apart from a few attempts to improve them,(agro-)climatic classifications have been subject to very little interest of late.

Instead, major efforts have been made to establish world maps of 'potential plant production', often based on relatively simple estimates of dry-matter productivity, Chang (1970); Lieth (1975). It should be noted, that expressions for 'potential plant production' usually relate to an 'ideal' crop (i.e. ever ready to produce and remaining in a vegetative stage). Several authors have contributed to steadily improving the concept and its necessary computations, de Wit (1968); Penning de Vries et al., (1973); Monteith (1972).

Serious problems still exist regarding both the definition and the utility of such a concept - since it expresses the unattainable. One way to solve the dilemma is probably by using instead 'actual plant productivity', understood as the maximum attainable productivity for a given, specific, crop. This would allow a modelling that takes the phasal development of the real crop into consideration, as exemplified by several works by IRRI, the International Rice Research Institute. One argument is, naturally, that 'actual plant productivity' is not an expression of productivity potential in the general sense.

Another main line of approach has been towards the development of more complex, synthetic expressions to reveal environmental possibilities for utilization. Most often, soil qualities and terrain constraints on mechanized agriculture have been added to agro-climatic considerations. The results are usually expressed as 'ecological zones', 'land capability classes' or 'crop suitability classes', often depicting national rather than international conditions. This is no wonder since the classifications must reflect conditions in relatively great detail to be useful, which of course makes them less practical for presenting larger regions.

TOWARDS AN ECOLOGICAL CLASSIFICATION OF AGRICULTURAL SYSTEMS

As mentioned above, a proper ecological classification must, preferably, include two elements: One expressing the main characteristics of the *environment*, here termed the *'econiche'*, into which any utilization system must 'passively' fit or adapt, because some environmental constraints cannot in practice be changed. The other element is one characterizing properties of the *utilization system* in its 'active' role of managing environmental factors, the *'ecotype'*. In the following, a possible guideline for making a classification will be preliminarily outlined.

During the selection of relevant criteria for the classification of the productive environment as well as the utilization system, factors limiting plant productivity are a natural choice to consider. Such criteria may also meaningfully apply to the classification of animal-based systems, as these are based on plant production.

The factors determining the productivity of an imaginary plant are mainly: 1) the energy environment, 2) the environment of matter used by, or at least influencing, the growth of the plant, including gaseous, liquid and solid state elements.

The energy environment must be characterized at least by such important features as photosynthetically active radiation and temperature. For the environment of matter, at least the gaseous CO_2, O_2, H_2O, as well as the liquid H_2O must be listed, and the extensive list of solid elements, briefly labelled 'plant nutrients', occurring mostly as simple ions in nature, must be added.

Environmental Niche - 'Econiche'

To characterize the *environmental niche*, within which utilization must adapt itself, the more important variables are: the energy flux (intensity and periodicity) and the water budget (precipitation and potential evapotranspiration). The conditions set by radiation/temperature and precipitation are, for all practical considerations, beyond the control of the cultivators: Utilization systems must passively adapt themselves to the conditions or perish.

The first characteristic describes the level of available *radiation* (for photosynthesis and the determination of air and soil *temperatures*). For the productivity of any plant, be it of C_3 or C_4 type, the photosynthetic radiation level is decisive (re: high or low energy plants). Equally important is the periodicity, expressed by the number and length of growing season(s) per year. Another, related side of the energy environment is expressed by the thermal growing season; it may here be conceived simply as the (coherent) time with temperatures over e.g. 4° C, assuming that to be the temperature at which plants begin to produce. In practice, this seems to correspond to an average monthly temperature of about 10° C.

Naturally, the photosynthetic flux + thermal level - not to speak of a well-conceived expression for plant productivity level and periodicity - would express better the energy environment of the growing plant, but since such measures are largely unavailable, thermal conditions may be used as a first approach. Using a few uncomplicated assumptions, e.g.

- that a minimum of 3 months is necessary for the cultivation of any cereal-crop,
- that the periodicity can be expressed as the number of subsequent months of thermal growth potential per year, and
- that an important difference in energy levels can be expressed by:
  a) 'low level': average monthly temperatures exceeding a minimum of 10° C.
  b) 'high level': average montlhy temperatures exceeding 15° C.

One may arrive at a simple division of the Earth's thermal agro-climate into familiar zones like:

- *the tropical zone:* continuous thermal growing period at a high energy level = 12 months, high level.
- *the subtropical zones*: one annual thermal growing period at a high energy level + another annual growing period at a low energy level, each at least 3 months.
- *the temperate zones*: only one annual thermal growing period at a low or high energy level (not falling within the preceding classes).
- *the polar and high-altitude zones*: absence of thermal periods sufficient for the cultivation of normal cereals, i.e. duration of growing period less than 3 months.

Evidently, this division is similar to those used in both Köppen's and Vahl's systems, although it has slightly differing basic definitions, partly inspired by those of Bayliss-Smith (1982). The relevance of the classification lies with the fact, that all plant production must adapt to the conditions set by the thermal climate if open-field production is considered - which is the case for any large-scale production.

An additional set of variables should be applied to the thermal agricultural zones to distinguish between areas of sufficient/non-sufficient *water availability* for utilized plants. Definitions here are somewhat difficult, because water-use/drought resistance is so variable among plants. As a simple solution for the definition of the duration of the period with sufficient water, it may be suggested to use the period during which precipitation exceeds/equals potential evapotranspiration, with the accumulation of up to e.g. 20 cm of water, while not allowing the duration of water-deficiency periods to exceed e.g. 5 days within the growing season. The 20 cm allowance for water accumulation is a conventional magnitude of water retention capacity for many soils. Similarly, the allowed maximum duration for drought-intervals of 5 days is based on the drought resistance of many cereals. Both figures can of course be refined by the use of tables expressing the percentage damage as a function of drought duration a.s.o.

Quite clearly, only periods of more than 3 months of coinciding thermal and hydrological sufficiency should be considered as natural growth periods. The thermally feasible periods for crop production can subsequently be characterized by water availability; e.g. insufficiency, general sufficiency for crops of low requirements, sufficiency for normal cereal requirements.

Utilization System - 'Ecotype'

The *active adaptation to the environment* includes improving and changing growth factors whenever possible. The main areas of intervention concern the supply and regulation of plant nutrients and water.

Regulating the availability of plant nutrient(-ions) is a natural consequence of the low supply-levels usually found in nature. The initial step to improve this condition is the disturbance of the natural balance between plants by interfering into their mutual competition by weeding and clearing.

Another, more conspicuous intervention is the concentration of nutrients in the area of immediate utilization/cultivation. This activity is a consequence of the fact that concentrations are not only normally low in nature but tend steadily to decrease as a result of soil exhaustion from utilization. Harvest loss is one of the causes of depletion. Others are losses from leaching, gasification and chemical fixation.

A concentration of nutrients is the normal solution to the problem of decreasing yields. Usually the farming activities reveal the concentration clearly, but it can also easily be diagnosed, for example, on the basis of the areal utilization pattern.

Some major types of solution to the concentration problem are as follows:

Natural concentration: concentration is only by natural weathering and decomposition. Vegetation has a tendency to establish a nutrient pool in the upper layers of soils by the combined activities of roots and leaf-losses. No artificial concentration is attempted.
Local concentration: nutrients are actively moved within the local area, usually the farmstead. Two subtypes can be distinguished:
Fallow storage/replenishment systems: In shifting cultivation storage takes place in the fallow vegetation during the fallow period. Nutrients are transferred from the vegetation (e.g. by swiddening) into the crops.
Infield-outfield systems: systems based on the transfer from one area, the so-called outfield to another, the infield, within the same unit of utilization. Infield-outfield systems are often operated with animals, usually ruminants, grazed in the outfield and temporarily kept in the infield, where manure is produced. Analogously, the systems can be worked on a purely vegetable basis (e.g. as in the African 'chitemene').
Natural concentration, but with increased availability: availability of nutrients increased without change in the total amount of nutrients - such as with ploughing etc. Such systems often include a 'top-turning' of the soil by which nutrient losses to deeper layers are counteracted.
Local concentration with atmospheric uptake: a subclass of the above, in which the concentration of certain elements is increased, such as nitrogen, by transfer from the atmosphere by using leguminous crops. Usually the systems are combined with crop rotations to increase the efficiency of nutrient use.
Concentration by import: the imported nutrients are usually applied in the form of inorganic chemical fertilizer compounds.

The classes described are arranged in the first place in a sequence based on a distinction between major types of 'soil fertilization', largely to follow the degree of complication of the fertilizing process. At the same time, the sequence possibly reflects main historical stages of development, although it should be kept in mind, that subsequent refinements may have produced sophisticated systems even within the more 'primitive' classes listed. Some 'fallow storage systems' (i.e. types of shifting cultivation) are highly complicated in spite of the basically simple principle of 'storing nutrients in fallow vegetation to achieve concentration for future crops'. This is in reality a concentration 'over time', in contrast to the infield-outfield systems concentration 'over area', see e.g. Christiansen (1978).

In the case of top-turning and natural concentration a kind of recycling principle is often implied. Even if tempting, a special class will not be suggested for the recycling and nutrient saving principle. Since recycling and nutrient saving is involved in most utilization systems this would imply difficulties; mixed cropping or crop-rotation is used in many of the major types of concentration.

The problem of classifying systems in which animals are a part may be solved by additional reference to their ecological function. The life of most animals, as in humans, is sustained by consumption of plants. The presence of animals should therefore be indicated by designating their ecological type and function, showing whether they are fed on wild or cultivated vegetation, or whether they are ruminant or non-ruminant animals. An indication of the type of production can be useful, such as whether the livestock is to be used for meat production or dairy production etc.

Like plant nutrients, water is subject to regulation with the purpose of increasing plant yields, although the ability to decrease of water concentration, the use of drainage, is perhaps just as important as the ability to increase water supply. Still, principles for the *concentration of water* seem to be applicable criteria for classification.

Very similar classes to those describing nutrient concentration may be proposed:

Natural concentration: The utilized area is rain-fed and naturally drained; the amount of water retained depends solely on soil water retention capacity.
Local concentration: Water is concentrated within the local area only. Two subtypes are distinguishable:
Local concentration by 'dry-fallow'-storage by which water is accumulated from year to year e.g. as by 'dry farming' to save enough water for a crop; 'replenishment over time'.
Local concentration, 'area to area'-type: water is taken from one part of a field, the catchment, and accumulated at another, smaller, recipient area, such as an 'impluvium'. The rainwater is gravity-led from one part of a field to another to supply the crops as required. A slightly different, nevertheless related, form is found, where natural changes in the water-level of a water body, such as a lake or river, recedes to leave the water-soaked former bottom for cultivation ('recessional irrigation', such as practicsed within the African 'fadama' cultivation).
Concentration by import: Water is imported from areas other than the local farm/village area. Two subtypes are distinguishable:
Import via inflow of groundwater. The water has to be brought within reach of the roots. This is in rare instances done by using capillary forces, as found in the 'chinampa'system in ancient Mexico and the 'niaye-'system in present Senegal. By these practices the cultivated surface is artificially lowered to bring the root-

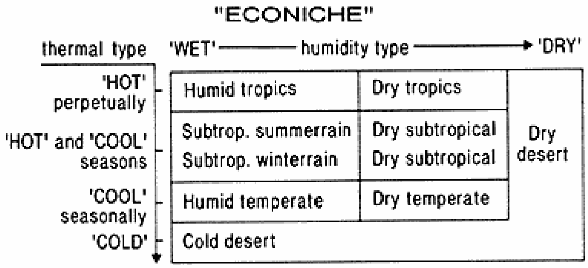

Fig. 4. The 'Econiche', a preliminary expression of agricultural potential and periodicity.

zone into contact with the capillary zone directly above the ground water-table.

However, water is usually brought to the surface by mechanical lifting devices of which numerous varieties exist.

Import via inflow of surface water. The water is taken from surface sources, such as rivers, by direct transference into a canal irrigation system. It can also be taken from reservoirs, such as from dammed lakes, formed behind small earth-walls (as with 'tanks) or behind huge modern, concrete dams.

Parallels to the classification of nutrient maintenance can possibly be drawn even further. As with nutrient regulation, the ideas of 'conservation' strategies also apply, both when it comes to physically saving water by establishing windbreaks and shelter belts and when it comes to selecting crops or mixes of crops that use scarce resources efficiently.

Another element of land utilization systems concerns the *use of animals*, especially in relation to the environment. The following classes may be considered:

Direct use of natural vegetation (grazing, browsing).
Direct use plus the additional use of stored, natural vegetation (grazing and stable-feeding). Manure +/-utilized.
Direct use of cultivated vegetation; fodder and wastage.
Direct use plus the additional use of stored cultivated produce (grazing, stable-feeding). Manure +/- utilized.

The first class may be subdivided according to the movements of animals into 'nomadic' and 'stationary' usage. Nomads may be divided into those following fixed routes as by transhumance, and those with wanderings determined by temporal, changing conditions, 'free nomadism'. Ranching is also a kind of direct use. Distinction may be made between guided and unguided grazing/browsing: rotational grazing is a form of guided grazing.

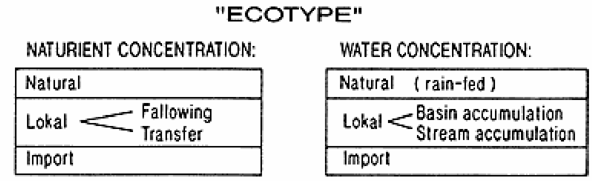

Fig. 5. The 'Ecotype', characterizing major ecological functions of utilization systems.

Ecological Classification

Based on the preceding facts in this article, an *ecological classification* will now be proposed based on two elements: One relating to the character of the environment seen from the point of view of utilization, *'the econiche'*, another relating to a description of the active ecological adaptation of plant and animal production management, *'the ecotype'*, expressed by the ways plant-nutrients and water are handled to achieve higher productivity, and how animals utilize vegetable matter. In conclusion, a classification will be suggested for further elaboration. It includes two elements: a) an indication of a) *agricultural niche*: the 'econiche' of the utilization system, and b) an identification of b) *nutrient/water management: ecological function:* the 'ecotype' of the system.

To indicate the types which have been identified, fig. 4 and fig. 5 may serve as illustrations.

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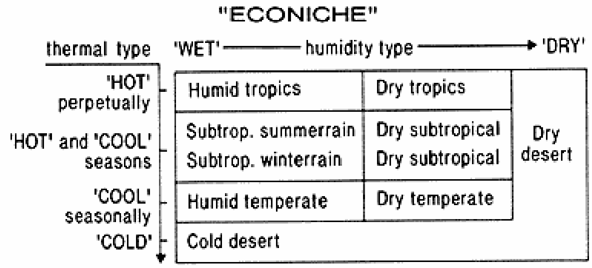

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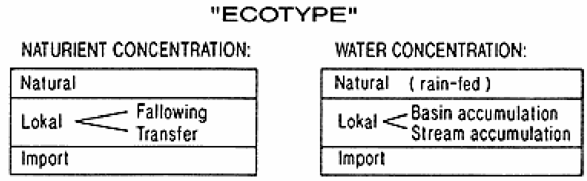

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