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THE RELATIVE STABILITY OF INDIAN VEGETATIONAL TYPES

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I. INTRODUCTORY

To the casual observer, most of the familiar types of vegetation seem to retain their general appearance and composition over long periods of time; what he remembers from his childhood as open thorny scrub (1) 8 to 15 ft. high, perhaps with here and there a grove of mangoes, still looks the same when he reaches manhood and even old age; and similarly for the open grassy plain, the sandy river bed with grassy tussocks, and the closed forest on hill and plain.

If his attention is drawn to the matter, the older man will quite probably tell you that there was tree forest in his youth supplying all local needs for timber, tools and fuel, where now you see only open thorny scrub; but sometimes, on the contrary, he will tell you that a certain tree jungle was only a stony gravel bank or open grass land in his youth. The close observer of such changes—we now term him a plant ecologist—quickly realises that, except in unfrequented parts of the country, change, not stability, is the order of the day for the vegetation occupying the soil. The old villager remembers only the outstanding instances, but the ecologist finds that it is exceptional in India to

find areas which do not yield evidence direct or indirect of having changed considerably from a former condition and of being likely to change further in the future. The tempo of these changes varies within very wide limits, being as a rule faster the more recently and intensely human influences have impinged on the area considered.

II. EXISTING VEGETATIONAL TYPES

India has a wide range of vegetational types corresponding with its exceptionally wide range of climatic conditions, from the edges of the eternal snow to the hot constantly moist forests of the Western Ghats and the hot continuously dry desert vegetation of Sind and Rajputana; also to the wide variation in soil from loose dry sand to stiff clays, laterite, black cotton soil, and the dark humus soils of the temperate hill ranges. A survey of the forest and shrub types of India and Burma was published in 1936 (2) and studies have been published, several of them in the Society's Journal, of non-forest types such as the low desert vegetation (3), lake side herbaceous (4), (5), (6) and aquatic floras, etc. In my presidential address to the Botanical Section of the Indian Science Congress in 1937 (7), I developed the thesis that forest was what is known as the climax vegetation (8), (9) over almost the whole of the country, with only relatively minor exceptions notably in the dry eastern areas and the tops of the Himalaya above timber line, and this view appears to be shared by the majority of writers on the subject.

For the purposes of this address, we need make only the simplest sub-division of the vegetative cover as we find it into:

(1) grassland,

(2) savannah forest (i.e., open woody cover with herb vegetation between),

(3) Scrub,

(4) Deciduous forests,

(5) Evergreen forests, and

though references may be made to aquatic vegetation, cultivated crops, the special vegetation of our estuaries, etc. It is proposed to consider representative occurrences falling into each of these sub-divisions from the point of view of their past history, known or deduced, the factors affecting their present apparent stability, and finally their probable future.

III. EVIDENCE OF CHANGE

It is necessary first to consider briefly in what direction evidence of past history may be available if looked for. Firstly, there may be written records as in the well-known instance of the hunting exploits of the Moghal Emperors in Etawah district; here the level tree forest with local heavy grass, then frequented by rhino, etc., has in 2-3 centuries become tortuous ravine land with thorn scrub and only poor thin grass.

Secondly, we frequently have direct archaeological evidence of which perhaps the best example personally known to me is just outside India in what is known as the Dry Zone of Ceylon, now under almost unbroken forest over hundreds of square miles, but 1,000 years ago supporting a great population, the ruins of whose cities and irrigation works are scattered throughout.

Less obvious evidence of a similar type is supplied in nearly all our hill tracts by traces of ancient terracing of the slopes, proving they have once been completely cleared and cultivated.

Again, the vegetation itself may provide useful evidence of changes which must have occurred or at least influences which must have been at work during the last century or so. A common clue is the presence in a forest area of a patch of growth of varying extent, usually on good soil or a warm slope, and near water, differing from the surrounding growth in specific composition and form, and characterised by the presence of big branchy shade or fruit trees such as mango, mahua and tamarind and often exceptionally large and branchy specimens of the jungle trees, also proving as definitely as any written record that here is the site of an old clearing and settlement with the manifold influences which man and his grazing herds formerly exerted in this spot and its vicinity.

Often associated with the type of evidence just mentioned but still less obvious to the layman and very liable to be overlooked by the botanist who is not also a forester, is evidence supplied by the average age and uniformity of the tree crop an area carries. A forest devoid of scattered trees which have reached the natural span of life of the constituent species cannot be in equilibrium with the habitat, and influences must have been at work accounting for their absence. As an example of this, (10), I may quote an apparently stable pine forest in Kumaun well covered with trees of all sizes except the biggest which other similar sites normally carry. Age studies showed that these trees despite their range in girth from 3′ to 6′ were all of very much the same age, 100—120 years (the natural term of life is over 200) and on closer examination traces of partial terracing were discernable here and there. It can hardly be doubted that the whole slope had once been cleared of trees for the shifting cultivation previously practised; further support for the deduction was available in the general historical records of the tract which shew that it formerly carried a relatively dense population.

This general type of evidence has to be accepted cautiously or the student finds himself begging the question he has set himself. The extensive hill tracts between Bengal, Assam and Burma offer a most interesting ecological problem in this way. Vast areas now carry a dense growth of bamboo (primarily *muli* or *Melocanna bambusoides*) with scattered trees of species mostly found in the wet tropical evergreen forest such as

Dipterocarpus alatus, Mangifera longipes, Amoora, etc. Clearings for shifting cultivation are known to become covered in time by this bamboo and to leave scattered trees of the original forest, and the natural deduction would be that the type has originated over whole area in this way, but much further evidence is necessary before this hypothesis can be considered as proved.

The example just quoted also provides an instance of another type of evidence to be considered, i.e., indications in the composition of the vegetation itself that it differs for no reasons apparent in the site and soil, from the type which is associated with such soil and site elsewhere. Thus, the soil and site in our example are often such as elsewhere carry closed evergreen forest including the species of which isolated examples are found standing over the bamboos or on steep slopes and in sheltered ravines. Such an area should, one deduces, also carry closed evergreen forest, surely must have done so in the past, and perhaps may yet do so again in the future if restraining influences are kept away or removed.

Other instances are provided by the predominance of thorny and inedible species in almost all the remaining woodland of our thickly populated districts, and by the predominance of the hardiest species (especially gregarious ones like *Shorea robusta*) in the more extensive forest areas. I have previously quoted (10) a striking example of this from the W. Himalaya, where a single spur rising from a river at 2,500 ft. to about 6,500 ft. carried residual forest at three levels; it had at the bottom almost pure stunted *sal* forest with a little thorny undergrowth of *Carissa*, *Randia*, etc.; then after a break a pure *chir* pine forest with no undergrowth whatever; and finally at the top pure oak. The oak is very hardy to lopping and had a mixture of *Rhododendron* and *Pieris* which was in far higher proportion in the opener fringe, than in the better stocked forest further from human habitation, these species being inedible to cattle and of poor fuel value.

The evidence so far considered has dealt with past changes; there may also be evidence of changes to come. One example from the plains and one from the hills will suffice. Many old woods of *sissu* (*Dalbergia Sissoo*) will be found to have no young *sissu* on the ground but a copious supply of *Holoptelea* which will replace the *sissu* as it dies out from old age. Similarly examples are common of a maturing blue pine wood with ample regeneration of silver fir but no young blue pine.

IV. AGENCIES OF CHANGE

We will next review the chief agencies at work on the vegetation likely to affect its stability and bring about changes, dealing firstly with injurious agencies and the opposite effects of removing or restricting them, and then with the results of intelligent human endeavour. Most of these agencies have been mentioned

already. To them must be added the natural changes taking place in new or disturbed soils with the passage of time.

1. **Clearing for cultivation.** This in India normally means the destruction of woody growth of some sort and its replacement by cultivated, usually herbaceous crops. Occasionally grassland is similarly treated.

2. **Clearing round cultivation and settlements** by removal of building material and fuel, sometimes with intentional destruction of trees to improve grazing or to keep away wild animals; burning and lopping for fodder are important contributory factors. The results vary with the original vegetative type, but the general effect is degradation of high forest to savannah types with open tree cover and herbaceous or shrubby undergrowth, the latter with the weeds of cultivation and waste places prominent. Where cattle are herded, nitrophilous vegetation becomes conspicuous. The trees tend to become limited in time to a few species, either useless ones or favoured fruit and shade trees. Invasion of introduced weed species frequently follows, *Lantana* and *Eupatorium* being outstanding examples which have so altered conditions that we cannot yet say what the ultimate outcome will be.

3. **Grazing.** All original vegetation is of course subject to the grazing and browsing of the wild animals naturally associated with the site, but on available evidence though this influences in some degree the proportions of the several component species, it does not affect the general type or form of vegetative cover. The grazing of domestic herds on the other hand is a totally different matter in that the intensity factor is increased beyond all proportion to the stock of wild animals they displace, and with fire constitutes the most influential agency now affecting the vegetation. Such heavy grazing in a forest usually affects it mostly through its deterrent action on the regeneration of the tree species; by trampling and exposure of the soil, conditions are rendered more difficult for the seedlings and such as survive are exposed to being eaten by the cattle, only some species being adequately protected by non-palatability. The intensity factor is important, for a light degree of grazing by reducing the undergrowth and exposing the mineral soil may actually facilitate the establishment of tree seedlings especially where there has been much accumulation of raw humus as in our fir forests. It will be noted, however, that in both cases the natural course of events will be altered by the introduction of the domestic grazing factor.

Considering herbaceous growth, grazing again exerts a very far-reaching influence, varying much with vegetative type and locality and grazing intensity. Inedible species are always favoured, e.g., *Cassia spp.*, *Asclepiadaceæ*, etc., as also are thorny ones, e.g., *Mimosa*, *Zizyphus*, etc., and ground lost by the more

edible herbs and grasses. On the other hand, grazing of grassland on old cultivation, etc., frequently prevents or delays its occupation by the coarse tall grasses.

The kind of cattle grazing is also very influential, the browsers, goats, buffaloes and to a less degree sheep, checking woody growth far more than cows and horses. Heavy grazing by browsers may turn dense high forest into grassland or scrub in a tree generation by inhibiting tree regeneration whilst the old crop slowly dies out; this is visible throughout the fir forests of the Himalaya.

The direct results of grazing are accentuated by the activities of the accompanying graziers who lop the fodder trees for their flocks and herds, encourage the extension of grassland by burning and girdling and meeting their own needs for building material and fuel.

4. **Burning.** Much has been written, mainly by foresters, of the effects of burning on the natural vegetation of the country, and it cannot be repeated here. The general effect is to degrade the vegetation to a form typical of a drier climate than is indicated by the meteorological records, thus moist evergreen forest is degraded to deciduous forest or grassland, deciduous forest to savannah, and moist coniferous forest to scrub or grass. Where the general facies is not much altered, the species composition is altered in favour of the fire hardy species; thus in the Gangetic plain, we hardly know what the natural forest was like before it was affected by human influences including burning, but there is ample evidence that most of the forests which are now almost pure *Shorea*, must have been much more mixed, with *Shorea* rare or even absent in many places. Again the present monsoon savannah type forests contain little except the most fire hardy species such as *Lagerstroemia parviflora Sterculia villosa, Bombax*, etc., though there are plenty of others now limited to favourable moister spots which could grow equally well with them if it were not for the periodic fires associated with human settlement.

5. **Abandonment of cultivation.** The succession of vegetation which occupies abandoned arable land provides one of the most conspicuous examples of ecological changes and all of us must have personal knowledge of several examples. Factors to be kept in mind are the duration and intensity of the cultivation which determine the extent of survival of remnants of the original vegetation, the surrounding vegetation which controls the relative ease of colonisation of the vacant site, and the incidence of grazing and burning. Long continued cultivation of land formerly under forest is liable to alter the soil both physically and biologically so radically that reoccupation by forest may be extremely slow. Instances could be quoted of old fields in the

middle of a forest which after 50 years or more still appear much as they must have done a few years after they were abandoned. However, more generally, grasses and other herbaceous vegetation quickly occupy the ground; shrubs and trees, especially those with effective seed dispersal mechanisms soon follow, particularly on old banks or bunds. Further development is too varied to discuss here, but in a general way, if restraining influences are light or moderate, there is a slow progression to the vegetational form appropriate to the climate and soil as indicated by undisturbed areas in the locality, and a still slower progression to the same specific composition. If the restraining influences are more effective, the progression continues to some stage short of this, and then appears to become stabilised as what is termed a subclimax.

6. **Stoppage of intensive grazing.** In any heavily grazed area where grazing has been excluded or considerably reduced, marked changes soon become apparent in the ground vegetation, often very quickly if conditions are at all favourable. There may be a marked increase of the more delicate edible grasses and herbs, but this may be followed by their displacement by the coarser perennial species (and so deterioration as grazing land). After this, progression usually takes place much as described in the preceding section towards the climax vegetation of the locality. Where the grazing ground was degraded forest, protection will have some of the effects just described, and may lead to copious regeneration of tree species re-establishing a closed tree crop which will bear for a century or more the signs of its past history.

7. **Fire protection.** It is only in the last decade or so that the far reaching effects of excluding fire have been realised, just as the great influence which burning has had on our vegetation was also not adequately grasped. Grassland is still mostly burnt annually, partly in the belief that it improves the species composition, but mainly to induce an early flush of edible new growth in the lean months from March to June. Burning grassland tends to check or inhibit tree growth, and so protection usually results in its development, e.g., *Macaranga* in the North Bengal *sal* tract. Burning in deciduous forests prevents or checks the development of all fire-tender species, and almost all evergreens are fire-tender; protection accordingly results in the closing up of the forest with a greater variety of species and in the addition of a proportion of evergreens varying with the climate and site and other factors. Fire protection of most types of scrub growth results in their progression to tree forest, e.g., temperate montane scrub to *Pinus excelsa*.

8. **Human control.** Our object in striving after an understanding of these changes is two fold, viz.,

(1) the purely scientific thirst for knowledge and understanding of ultimate causes and

(2) the application of the knowledge gained to the control of our environment to make it conform to our wishes.

Much long established agricultural practice is of course the application to the control of vegetation of experience gained by long experience and much trial and error experiment. The proper management of Indian grassland and grazing to which so much attention has been drawn of late, is a big field which is calling most urgently for a large force of scientists. I leave this aspect of my subject to those more competent to describe it. The introduction of systematic forest protection and management some 70 years ago has given results in all parts of this country which are full of interest and importance to the student of ecology. The countless instances where forest growth has since been completely destroyed right up to the legal boundaries then laid down, so that the protected forest is mistaken for an artificial plantation, may first be cited as a conspicuous feature. Within the forest the most important changes have resulted from protection against uncontrolled felling, from fire protection and from limitation or local exclusion of grazing. Again only one or two instances can be quoted. There are many examples also where inferior scrub has now developed with protection to valuable productive forest. In Bengal and Assam, a dense evergreen undergrowth, which has developed in *sal* forests, has completely inhibited the natural regeneration of the *sal*; *sal* however is by far the most valuable timber tree, so that to maintain it and get up a new crop of *sal*, special measures have to be taken to replace the evergreen undergrowth by a light grass growth, by cutting and burning. Ecologically speaking, a climax forest of unknown composition but evidently largely evergreen and probably with only local patches of *sal* on suitable sites has in the past been converted by human agency probably through grassland and savannah into a nearly pure *sal* sub-climax type which would progress again towards the climax with continued fire protection, but for timber production purposes has to be brought back to and maintained at the *sal* fire sub-climax. Just as the selective destruction of useful constituents of a mixed vegetation has been a marked feature in the past, so the selective protection and extension of desirable species is an important objective of intelligent management, and is gradually bringing about far-reaching changes in our woodlands, and in similar ways it is to be anticipated it will do the same in our managed grasslands and mixed grazing areas. The opinion has been expressed (11) that "India has no natural grassland area", whereas it seems quite likely that an increasing area will have to be maintained by artificial control of other vegetational types.

V. CHANGES IN PROGRESS IN DIFFERENT TYPES

1. Grassland

(*a*) *New riverain grass of North India. Saccharum spontaneum* is the characteristic species and may be maintained for some length of time by flooding with redeposition of sand by burning and grazing. In time however it very usually progresses to the *khair-sissu* and *Populus-Tamarix* types of forest. As a type it is always being reproduced in suitable localities, but on a given area is shortlived.

(*b*) *Older riverain grass of North India.* Grassland of various types is typical of the more stable lower alluvium. The grasses are mostly tall and coarse but provide valuable grazing from new growth after burning. The wetter sites often remain under grasses such as *Phragmites Karka* and *Saccharum procerum*, etc., until silt deposition raises and dries them but the drier and higher sites are slowly colonised by tree growth, fire hardiness and often frost hardiness being essential to success. Fire protection results in increase in the tree growth and it is evident that the grassland would soon progress to monsoon forest as the next stage. The higher old alluvium also carries a great deal of grassland again of tall coarse grasses such as *Anthistiria gigantea, Erianthus spp.*, etc., with *Imperata* (12). The results of protection indicate that much of this is also fire conditioned while other parts appear to be old clearings and will progress to monsoon forest notably *sal* forest (13).

(*c*) *Temperate grasslands of South India Hills.* Ranganathan (5) and Bor (6) have recently written on this type the former holding it to be a stable true climax, and the latter believing it to have been mostly preceded by the evergreen forest now limited to the sholas persisting only on favourable sites; I had previously (7) upheld the latter view.

(*d*) *Alpine grasslands.* Detailed studies are wanting but this may well be a true climatic climax.

2. Savannah types

(*a*) The riverain savannahs have been mentioned with the evidence that whilst they may frequently be a natural stage in the primary succession from river deposit to closed forest; they tend to be maintained as such by fire and grazing.

(*b*) Deciduous savannah forest is met with all over the hills and plateaux of Central India especially in the rather drier tracts and sites. In many parts progression to closed forest can undoubtedly take place with protection but other parts may well be viewed as the climax type.

(*c*) *Thorn savannah,* May be taken to cover much of the open forest of the Punjab *rakhs* and the open dry *Acacia* forests of the older alluvium and Central India. Evidence can be found indicating that much of the latter owes its existence to the degradation under human influences (14) from the drier variations of the deciduous monsoon forest but the Punjab semi-desert type though anything but free of human influences, is not far removed from the climax type. How rapidly the *rakhs* are disappearing is known to every resident in and visitor to the Punjab.

3. Deciduous forests

The summer deciduous monsoon forest is perhaps the most characteristic in India. It includes the *sal* and teak bearing forests occupying most of the remaining forest area and has provided most of the examples already quoted above of change and human influences. It is indisputable in many places that it has displaced evergreen forest and abrupt changes are constantly met with which are definitely not traceable to changes in rock or soil. Owing to the sensitiveness of evergreen seedlings to exposure and still more to fire, and probably to the soil changes which have taken place, the return of the evergreen is usually a very slow process and the deciduous type appears very stable. At the same time, though composition may be different, the general form of the deciduous forest is probably the true climax vegetation of a great part of the country.

The *khair-sissu* forests of new riverain soil have already been mentioned and provide one of the best available examples of a type which is always only a phase (sere) in vegetational history. It never regenerates itself on the same site but provides shelter for the establishment of a new stage on the way to the typical monsoon forest, a phase characterised by such trees as *Holoptelea, Albizzia, Bombax* and *Adina.* In drier climates, the poplar—*tamarisk* forest gradually changes to the thorn forest of the upper Indus basin. Soil changes are obviously closely associated.

The status of our rather limited temperate winter deciduous forest is less clear, but it is certainly frequently succeeded by coniferous forest or evergreen oak. Elsewhere it seems to be stable and conditioned by soil and moisture conditions.

4. Shrub types

Except for desert scrub and alpine scrub (notably *Rhododendron* spp.) all the main scrub types met with appear to be quite definitely ascribable to degradation types from high forest, or several stages in primary or secondary succession. Examples are the shrubby growth of *Wendlandia, Melastomaceæ,* etc., of the south, *Dodonæa Woodfordia, Adhatoda,* etc., of the north, *Indigofera, Spiræa,* etc., of the temperate hills, and the dwarf mangrove of our deltas.

5. Evergreen forest

The moist tropical evergreen forest appears to be the climax type wherever the annual rainfall exceeds 80" and the dry season is not prolonged (2). If this is correct it must once have occupied a much larger area than it does now, even allowing for its possible absence on unfavourable soil types (15). Mention must be made of our tidal forests as these are so obviously changing as the land is raised higher and higher by deposition of silt, and by the varying salinity of the water submerging them. Our coniferous forests as a whole are decidedly stable though examples of the fluctuating equilibrium with broadleaved forest and between the several species of conifer have been mentioned.

In conclusion, a few remarks are called for on the nature of the climax vegetation to which repeated references have been unavoidable, the end stage to which all existing vegetation is presumed to be progressing for the first (primary succession) or subsequent (secondary) time. Still the most widespread view is that developed by Clements (8) that for a given climate both vegetation and soil tend to develop to a single climax form whatever the initial differences; the climax vegetation is not expected to be absolutely uniform as there will always remain local factors opposing the climatic ones checking attainment of the climax (giving us a preclimax) or permitting over-stepping to a more advanced stage (a postclimax). Other workers find themselves unable to accept this monoclimax view and consider that each markedly different type of site within a climate has its own climax of equal status with the rest, and consider this multiple climax conception to fit better the available information (15). The difference between the two views has perhaps been overstressed in some quarters and is perhaps not of very great practical importance (9).

The object of this address is to invite attention to the widespread occurrence of vegetational change both forward or successional and backward or retrogressional, and to the importance of the study of these phenomena with a view to their control for the benefit of the country. To what extent that objective has so far been attained may be indicated by the number and scope of ecological contributions to the Society's Journal in the future. Although Volume I has a useful paper by Dr. Dudgeon, there have been very few since.

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