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ANTHROPOGENIC CHANGES IN VEGETATION: MONITORING, EVALUATION, AND PROGNOSIS

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The need for the monitoring of vegetation is established in connection with its increasing alteration under human influence. The theoretical and methodological principles of botanical monitoring, the estimation of the level of vegetation degradation, and the prognosis of anthropogenic transformation are described.

The plant cover of our planet is changing rapidly under the influence of human activity. The process of anthropogenic changes, or vegetation synanthropization (Falinski, 1971, 1972; Gorchakovskii, 1979; Kostrowicki, 1982; Olaczek, 1982), has many undesirable consequences: the extinction of a number of plant species, a general impoverishment of the flora, a decline in the genetic diversity of certain species, structural simplification, unification, and a decline in the productivity and stability of the plant cover (see Table 1).

Infertile or unproductive anthropogenic deserts arise during the anthropogenic degradation of vegetation under severe pressures in place of plant communities formerly of great and diverse economic value. In this case the original plant cover cannot be restored even after the complete protection of these regions from economic exploitation, while recultivation requires the expenditure of great labor and resources. Vegetative degradation in some regions and sites has taken on a threatening and even catastrophic character. Thus, intensive grazing results in desertification in the arid ecosystems of Turkmenistan (sourthern part of the Kara-Kum). This process takes 8-10 years. The total production of biomass and forage declines by 20% during the first half of the period and by 50% during the second half with a gradual transformation of pastures into badlands. At the same time, wind erosion increases (Nechaeva et al., 1979; Kharin et al., 1983). A suppression in the lichen cover and an inhibition of shrubs and subshrubs are observed in the tundra of the Chukotski Peninsula during the stage of intensive sheep grazing. The former plant cover is completely destroyed during the slaughtering stage (drive routes, corrals, holding pens) (Polezhaev, 1980). The process of plant degradation is bound to intensify in the near future.

Botanists and ecologists must study thoroughly the patterns of vegetation synanthropization for the utmost delay or cessation of the process of the exhaustion of plant resources and to assure the preservation of the riches of the plant world in all their diversity. Of great significance in this connection is the organization of a service for monitoring the condition of the vegetation, the development of methods for evaluating the degree of the anthropogenic degration of essentially natural plant communities, and also the prognosis of the likely changes in the plant cover under human influence.

MAJOR PRINCIPLES OF BOTANICAL MONITORING

Botanical monitoring is a subsystem of biosphere monitoring. This is a permanent service for tracking the condition and level of anthropogenic changes in the vegetation, primarily at sites of particularly intense economic exploitation. The goal of monitoring is a timely warning concerning any situation where the anthropogenic pressures on plant communities exceed the permissible norm, when the danger arises of a sharp decline in community productivity or there is a threat of extinction of rare and valuable plant species. On the basis of this information the appropriate organizations and departments concerned with the exploitation of vegetation must take urgent measures to modify the conditions of exploitation of the plant resources in the given region and to reduce the level of anthropogenic pressures.

Monitoring can be based on a determination of the degree of difference between the real

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TABLE 1. Forms of Manifestation and Ecological Consequences of Plant-Cover Synanthropization

Flora	impoverishment	Local
Flora	impoverishment	Global
Flora	evolutionary consequence	Decline in genetic diversity of species
Flora	evolutionary consequence	Fractionation and isolation of population
Flora	evolutionary consequence	Introgressive hybridization between earlier separate taxa
Flora	evolutionary consequence	Appearance of endemics of technogenic substrates and polluted sites
Flora	substitution	endemic elements by cosmopolitan elements
Flora	substitution	stenotopic elements by eurytopic
Flora	substitution	autochthonous elements by allochthonous
Plant communities		Blurring of regional boundaries
Plant communities		Impoverishment of composition
Plant communities		Structural simplification
Plant communities	substitution of natural native communities	by derivative communities
Plant communities	substitution of natural native communities	by synthropic communities
Plant communities	substitution of natural native communities	by crop communities
Plant communities		Convergence
Plant communities		Decline in ecological and phytocenotic diversity
Plant communities		General unification
Plant communities	decline	in productivity
Plant communities	decline	in stability
Ecosystems	transition	from higher level of organization to lower
Ecosystems	transition	from higher energy level to lower
Ecosystems	decline	in productivity
Ecosystems	decline	in stability
Biosphere		Irreplaceable loss of genetic resources
Biosphere		Decline in primary production

(actual) condition of the vegetation at some site and the potential or near-potential plant cover, represented by a system of protected territories (including reference regions).

The arsenal of means of botanical monitoring includes remote indication and visual observations from earth satellites, airplanes and helicopters, space and aerophotographs, terrestrial visual observations, observations of plant communities and populations of rare plants on permanent and temporary test areas, the removal of indicational botanical samples (tests), and the compilation of various geobotanical maps, including prognostic maps.

CONCEPT OF POTENTIAL NATURAL VEGETATION

The conept of the potential natural vegetation was first formulated by Tüxen (1956). This concept was later developed and refined by other researchers. By potential is understood the vegetation that can form at a given site after a specific interval of time following the complete prohibition or significant restriction of economic exploitation. The duration of the period of restoration of the potential plant cover depends upon the degree of disturbance of the natural vegetation, climatic and soil—substrate conditions, and other environmental factors, as well as the duration of the ontogenesis of the dominants of the major stratum in the phytocenoses. The restoration period usually lasts from 30-50 to 100 years.

The potential-vegetation maps in most cases differ appreciably from the maps of the so-called restored (preagricultural) vegetation, widely distributed in the USSR, and even more so from the maps of climatic vegetation developed, for example, in the USA.

Restored-vegetation maps show the plant cover believed to have existed on a given territory before the onset of active human impact on the natural vegetation. However, the changes in environmental conditions caused by both natural and anthropogenic factors (tilling of the earth, creation of ponds and large reservoirs, change in level of ground waters, swampification, swamp drainage, intensive livestock grazing, soil erosion, climatic changes due to deforestation, petroleum extraction), along with the impoverishment of the genetic resources of the local flora, in most cases preclude the natural restoration of the original vegetation on a given territory, even after absolute protection is established. Thus, for example, the steppes, completely destroyed in a number of the plains regions of the European USSR but shown on restored-vegetation maps, can no longer be restored. Consequently, restored-vegetation maps contain information on a past stage in the development of the plant cover while ignoring the significant environment changes caused by human activity.

With regard to climactic vegetation, its development requires many hundreds and even thousands of years, and under modern conditions, with intensifying anthropogenic pressures, the climax has become virtually unattainable.

In contrast to restored vegetation, reflecting a lost and irretrievable past, and climactic vegetation, reflecting a hypothetical, unattainable future, the potential vegetation is that which is or may realistically be present on some territory given the observance of scientifically based norms of protection and economic exploitation, that which must be preserved or restored (if the alternative of the transfer of these vegetation regions to other land categories is ruled out), and that which nature can yield by its own forces or with the help of man. The potential vegetation represents the most productive plant communities and stable under the local conditions. This is not only a natural reference, a sample of how much more productive the natural plant cover might be in a given region and a given ecotope, but also an object of economic exploitation. The gene pool and cenose pool of the plant world and the biosphere as a whole can be protected only if the natural vegetation is preserved on a portion of the land in all large natural regions.

Potential-vegetation maps reflecting the real ecological potential of individual regions and habitats are of great value for evaluating the effectiveness of the utilization of various land areas, for planning a rational utilization of nature, monitoring the plant cover, and predicting its likely changes.

A map of the vegetation of Europe in a scale of 4,000,000, including the European USSR, is now under development by the collective efforts of a number of European nations and the USSR. The map will show natural vegetation; however, at the given scale it will correspond to the potential vegetation. There is a clear need for the development of similar maps for the Asian part of the USSR, Soviet Central Asia, and the Caucasus, as well as a number of medium- and large-scale maps of the potential vegetation for individual regions of the nation.

REFERENCE REGIONS OF VEGETATION

The condition and level of degradation of plant communities is estimated by comparison with regions that have a natural or near-natural (quasinatural) vegetation characteristic of the given natural region and little affected by human activity.

In addition to the existing categories of protected territories (biosphere reserves, typical reserves, national or natural parks, game reserves, natural monuments), a network of reference vegetation regions must be established and developed. The purpose of reference regions (genetic reservations) is to characterize the diversity of natural and quasinatural plant communities typical of the given natural region, to serve as models of the composition, structure, and productivity of individual types of plant communities, as stores of the gene pool and cenose pool of the plant world, and as a base for stockpiling seeds for the restoration of multi-species grasslands in place of exhausted pastures and for the restoration and extensive reproduction of disappearing and especially valuable plant communities. Such regions should be set aside in individual management units — in tree farms, state farms, and collective farms.

The major requirements for reference regions are representativeness, floristic and cenotic diversity, and adequate size. The network of such regions must reflect the entire diversity of zonal and regional types of phytocenoses. The greatest possible floristic richness of the reference regions and diversity of their component communities must be sought. The size of the regions must be sufficient to assure the integrity of the ecosystems, their stability, the preservation of genetic and cenotic diversity, and the normal course of microevolutionary processes.

Furthermore, vegetation regions within the existing network of protected territories (reserves, national parks, game reserves, and natural monuments) can be used as references for monitoring purposes.

REGIMEN OF PROTECTION AND EXPLOITATION OF REFERENCE REGIONS

Reference regions can successfully perform their function only if the regimen of protection and exploitation necessary for the maintenance of their composition and structure at the original level is established for them.

Simple protection and withdrawal from economic exploitation often does not assure the performance of this task. This refers primarily to grassland plant communities (grass stands) — the steppes and meadows. The celebrated Orenburg Steppe, described in the work of P. Pallas, P. I. Rychkov, and later by É. A. Éversmann, S. S. Neustruev, and the writer S. Aksakov, once (200-250 years ago) represented boundless open spaces, a sea of waving feather grass, with grazing herds of wild horses (tarpan) and antelope (saiga). Many marmots and other burrowing rodents were found on the steppe. The nomadic inhabitants, who engaged in livestock raising, set fires to burn the dry grass annually in the spring and sometimes in the fall to preserve the fertility of the steppe pastures. The grazing of ungulates, the activity of burrowing rodents, and fires were necessary conditions for maintaining the composition and structure of the steppe vegetation.

Our observations in the Orenburg steppe and the steppes of the Trans-Ural Region showed that a radical change in the steppe vegetation is underway at those sites where the effect of grazing and fire is excluded. Shrubs (ground cherry, dwarf almond, *Filipendula*, black-berried cotoneaster, etc.) are spreading here, displacing feather grass, sheep's fescue, and other sod grasses and forbs. The development of shrub thickets in place of steppe is resulting in the local extinction of many species of steppe plants.

The Khomutov Steppe, situated 20 km from the Sea of Azov (Donets Oblast, Ukrainian SSR) prior to the Great October Socialist Revolution was under the control of the Don cossacks and used to pasture young horses. Many burrowing rodents were found in the steppe. However, the marmots were later extirpated, and only in 1933 were they again introduced from the Streletskii Steppe. In 1947 the Khomutov Steppe was declared a reserve. The conditions on the reserve resulted in the mesophytization of the steppe vegetation and a strengthening of the position of mesophilic grasses, in particular narrow-leaved meadow grass and awnless brome. Hay is now cut occasionally; however, it has not been possible to halt completely the process of the mesophytization of the steppe vegetation (Osychnyuk et al., 1976).

A similar situation has been noted in the meadow steppe of the Central Black Earth Biosphere Reserve (Bazilevich and Semenyuk, 1982). Here, the grass stand of an absolutely protected steppe is of a mesophilic aspect. Moderately grazed pasture is characterized by an increase in the species diversity of the grass stand and an increase in the role of steppe species. However, an impoverishment of the grass-stand composition is noted when the grazing pressure is greater than normal.

The meadow flora and vegetation in the boreal (coniferous-forest) zone has developed in river valleys, where treelessness is maintained by more or less prolonged flooding during the spring floods, and in dry valleys, where treeless glades or glades covered by sparse forest have appeared sporadically during the prehistoric epoch in the forests (at wind-fall or storm-break sites, at sites of the accumulation of deep snow or ground-water discharge), as well as in the mountains near timberline, where competition from woody plants is moderated. The area of dry-valley meadows has expanded considerably during the historical period as a result of deforestation.

The exclusion of regions of dry-valley meadows in the forest zone from economic exploitation results in their overgrowth by shrubs and forest, which is accompanied by the local extinction of the representatives of meadow flora. This is clearly shown by the Visimskii Reserve (Central Urals), where about 30% of the flora of higher plants is accounted for by meadow species. As shown by observations in Moscow Oblast at the Malinskaya Biological Station of the Biological Institute, Academy of Sciences of the USSR (Rabotnov, 1978), the species composition of unmowed-meadow communities is steadily impoverished, while an appreciable grass and forb diversity and the former dominant composition were preserved and the level of community productivity remained unchanged in a mowed portion.

In Khoperskii State Reserve the exclusion of boggy and true floodplain meadows of low and medium levels from economic exploitation resulted in an impoverishment of their species composition, an increase in the role of large-stemmed sedges and forbs, and a decline in the forage value of the grass stand. The swampification of such meadows or their overgrowth by forest occurs during prolonged protection. The area of true floodplain meadows in the reserve has declined by 1.5-fold during the last 35 years; according to the botanists studying these meadows this phenomenon is due to the cessation of hay mowing (Titov et al., 1984).

Observations made at the desert field station in the Central Kara-Kum showed that the vegetation of desert pasturage passes through the following stages under protected conditions: I) restoration period (seven years), II) period of greatest productivity (five years), III) period of initial suppression (five years), IV) period of suppression (after 17 years protection). During the period of suppression the productivity of the pasturage declines significantly, the soil surface is compacted, and synusiae of the moss *Tortula desertorum* and certain lichens occupy from 45 to 50% of the surface (Nechaeva et al., 1979). This shows that the moderate grazing of wild or domestic animals is a necessary condition for maintaining the stability and productivity of desert vegetation; prolonged, absolute protection gives negative results.

All this shows that the absolute protection of reference regions does not solve the problem of conserving the flora and vegetation of steppes, meadows, and deserts. The best results can be attained if protection from undesirable effects on reference regions is combined with a regimen of moderate economic exploitation.

Therefore, the categorical demand that all forms of economic impact on reserve vegetation be prohibited must be recognized as invalid. This principle is even more inapplicable for reference vegetation regions. A dogmatic approach is inappropriate here. Reference regions require a regimen of protection and exploitation consistent with the conditions under which the corresponding vegetation types, plant formations, and their combinations developed. T. A. Rabotnov and A. A. Nasimovich (1982) recommend the obligatory inclusion of ungulates (horses) into reserve steppe biogeocenoses with the restoration of the earlier-established species composition of burrowing rodents and their numbers and, on reserve meadows, moderate hay mowing with the application of phosphorus and potassium fertilizers in small doses.

ESTIMATION OF LEVEL OF ANTHROPOGENIC DEGRADATION OF VEGETATION

Monitoring must be based on convenient and reliable methods for estimating the condition of plant communities and the level of their anthropogenic degradation. Such methods are still insufficiently developed. E. Hadač (1978) used the indicator of the proportional involvement of ruderal species in the flora of a region of Czechoslovakia to estimate the level of human impact on the natural plant cover. Our studies showed that the criterion of the proportional involvement of synanthropic species in the composition plant communities, especially grass-land communities, can be successfully employed to estimate the degree of their degradation.

Synantropic species should include both local and nonlocal plants whose position in the composition of plant communities is intensified when anthropogenic pressures increase. The most complete and detailed classification of synanthropic plants was proposed by Kornas (1982). We present this classification with slight refinements:

Endemic (apophytes):

A. Permanently established in habitats created or altered by man (euapophytes);

B. Penetrating temporarily (ephemeral apophytes);

C. Originating from crops (ekiophytes).

Ecdemic (anthropophytes):

A. Permanently established (metaphytes):

a) relatively old immigrants, earlier than 1500 B.C. (archeophytes);

— introduced (adventive archeophytes),

— created by man (anthropogenic archeophytes),

— surviving only in man-made habitats (resistant archeophytes);

b) new arrivals, after 1500 B.C. (kenophytes).

B. Not established permanently (diaphytes):

a) penetrating temporarily (ephemerophytes);

b) originating from crops (ergaziophygophytes).

Synanthropization is essentially a process of the adaptation of the plant world to environmental conditions changing under the influence of man. During the course of this process, the species most adapted to the new, man-made conditions survive and disperse. In most cases these are less productive and valuable species, less desirable for man.

Thus, three stages of pasture degradation can be distinguished for meadow and steppe vegetation where livestock grazing is the major factor of influence: Stage I corresponds to moderate grazing, II to intensive, and III to extreme. In one of our previous papers (Abramchuk and Gorchakovskii, 1980), such indicators as the proportional involvement of synanthropic species in one or another association and their abundance according to the Drude scale were used to estimate the degree of degradation of the meadows of the forest-steppe Trans-Ural Region. It was established that a small number (1-7) of synanthropic species with a negligible abundance (sol.) penetrate the grass stand during the first stage of degradation; the number of synanthropic species (7-23), of which one emerges in the role of codominant (abundance of sp.—$cop._1$), increases during the second stage. The third stage is characterized by a general impoverishment of floristic composition and accordingly some decline in the number of synanthropic species (7-11), but with the emergence of one into the position of dominant (abundance of $cop._2$—$cop._3$). The convergence of meadow communities (their entire diversity reduced to several associations with a dominance of *Deschampsia caespitosa*, *Trifolium repens*, and *Potentilla anserina*) and a decline in productivity are observed in the course of degradation.

Similar patterns were also demonstrated in the steppes of the Ural—Ilek Interfluve (Gorchakovskii and Ryabinina, 1981), where stage I of pasture degradation is characterized by fescue, *Poa bulbosa* (in mixtures with fescue, feather grass, or forbs), or *Stipa capillata* communities with four to eight synanthropic species encountered singly or sporadically. During stage III they are replaced by floristically extremely impoverished and monodominant communities with a predominance of a synanthropic species (*Ceratocarpus arenarius*, *Alyssym desertorum*, or *Kochia prostrata*). The grass-stand productivity declines.

An increase in the proportion of synanthropic species (in indicators of their abundance and proportion relative to the total floristic composition) was also demonstrated in the course of the degradation of relict European alder forests of Central Kazakhstan (Gorchakovskii and Lalayan, 1981).

However, the Drude scale for estimating abundance is insufficiently precise, and its use does not eliminate the subjectivity of estimates. In continuing our studies in this area, we attempted to find more objective criteria enabling an estimate of the level of degradation of meadow communities in order to improve the methodology (Gorochakovskii and Abramchuk, 1983). In addition to the number and abundance of synanthropic species, we used the indicator of their proportional involvement in the composition of the aboveground phytomass. Samples for estimating productivity were taken not only with respect to agrobotanical groups, but synanthropic species were specially distinguished.

It was found that the floristic composition, structure, productivity, as well as the proportional involvement of synanthropic species in the composition of the aboveground phytomass of floodplain meadows change appreciably during pasture degradation. In the first stage, synanthropic species comprise a negligible contaminant, being encountered singly or sporadically and forming no more than 10-15% of the aboveground phytomass. In the second stage they acquire dominance in the grass-stand and account for about 50% of the aboveground phytomass, while in the third stage they pass to absolute dominance (80-90% of the aboveground phytomass). The floristic composition of the meadow communities is impoverished as degradation continues (41-46 species during stage I, 33-34 during II, and 18-23 during III), and both the number of synanthropic species (from 6-9 to 13-14) and their percentage involvement with respect to the total species composition (from 13 to 78%) increase.

Thus, the estimation of the level of pasture degradation of meadow and steppe communities and the assignment of these communities to one or another stage is facilitated by indicators of the proportional involvement of synanthropic species in their composition: a) the total number of synanthropic species; b) the percentage synanthropic species with respect to total species composition; and c) the percentage phytomass produced by synanthropic species with respect to the total aboveground phytomass.

Delichenization — the decline in the proportion of lichens within plant communities — occurs in the tundra under the influence of sheep grazing. Delichenization is accompanied by the grassification (meadowization) of the tundra (Andreev, 1983). This indicator can be used to estimate the level of the grazing degradation of tundras.

The level of degradation of grassy plant communities can also be judged by the results of a population-ecological analysis of their major components (age structure and density of populations, individual viability). For example, it has been noted that in the southern semidesert in communities with a dominance of *Artemisia tjanschanica* and *A. lercheana* the relative numbers of senile individuals can be judged by an indicator of the degree of grazing degradation (Vorontsova, 1967, 1971).

Recreation is gaining increasing significance in high-mountain regions (tourism, skiing, berry and mushroom collection, etc.). Road construction, expansion of the trail network, trampling, the compacting of the snow and soil, and the enrichment of the soil with nitrates result in the suppression of the viability of some species and the activation of others, an alteration of the vegetation, the appearance in alpine regions of plants not previously characteristic of these regions, and the formation of ruderal plant communities.

As shown by studies conducted in Rocky Mountain National Park (Colorado, USA), the ecosystems in the high mountains that are most easily disturbed are associated with moist soil, followed in susceptibility to disturbance by the ecosystems of tall-grass meadows, further by rocky deserts, and finally by peat ecosystems. As a result, the following scale for estimating the recreational impact on vegetation was proposed (Willard and Marr, 1970):

0 - no impact, plant cover is undisturbed;

1 - slight impact, plant cover is 100% natural and only slightly suppressed in places;

2 - ecosystems clearly affected, but vegetation is 85-90% natural;

3 - ecosystems clearly altered, vegetation 25-85% natural, its normal development noted only in protected sites, viability of plants attenuated, soil eroded in places;

4 - ecosystems radically altered, natural vegetation 5-25% of the original and has disappeared with the exception of some protected sites, soil horizon A exposed on a large area and eroded;

5 — ecosystems disrupted, vegetation 0-5% of original, plants that are present survive in very protected sites or the growth of the plants is suppressed, the soil horizons B and C are exposed as a result of erosion.

The level of degradation of high-mountain meadows during recreational use can be judged by the ongoing growth of the tree stand (Nikodemus, 1982), a convenient method for the determination of which was developed by I. Liepa (see Maurin' et al., 1978).

An integral indicator of the level of anthropogenic degradation of the ecosystems and plant cover of high-mountain regions, according to our data, may be the degree of descent of the actual timberline with respect to the potential. The greater the gap between the actual and potential timberlines, the further the degradation of the high-mountain ecosystems has progressed and the more pronounced are the negative consequences of this phenomenon (intensification of avalanche activity, soil erosion, decline in productivity of plant communities).

The magnitude of this indicator can be established on the basis of a number of biometric and phytochorologic traits, including the correlation between tree height and the absolute elevation of the locality, the magnitude of the annual growth of trees in height, and the frequency of encounter of live trees, the remains of dead trees, and microgroupings of forest grasses and shrubs above the actual timberline. Considering the high indicational significance of the timberline, monitoring should include continuous observation of the dynamics of this important biographic boundary in mountain regions.

REMOTE MONITORING OF ANTHROPOGENIC CHANGES IN VEGETATION

The study of natural biological objects, including vegetation, from a distance — from airplanes and satellites — now finds increasingly wide use. The procurement of images during remote studies of natural objects is based on the recording of electromagnetic waves reflected or emitted by various objects. The reflective capacity of the vegetation is variable and depends upon the composition, structure, productivity of plant communities, and on their seasonal condition. Photographic systems, magnetic tapes, and television systems are used to obtain videoinformation.

Remote receivers of radiant energy are divided into "active" or "passive." Passive receivers record the electromagnetic waves reflected (or emitted) by natural objects; active receivers have an intrinsic source of irradiation (Kharin, 1975, 1980).

Passive remote indication is done in the visible infrared and microwave zones of the spectrum. It enables demonstration of characteristics of the composition, structure, phenological rhythms, and dynamics of plant communities and establishment of the degree of difference between the vegetation of protected (reference) and intensively exploited territories. Repeated photographs at different times make it possible to record the changes in the reserve of phytomass (Vinogradov, 1982).

In the USA an image of a single territory is made every 18 days from satellites of the Landsat-2 type circling the earth; moreover, the photograph is immediately transformed into a cartographic projection. This permits the inventory of pastures, estimation of their forage characteristics, and demonstration of the dynamics of plant communities and the change in their productivity (Kharin, 1980). Subsatellite aerophotography is a necessary component in the monitoring system.

Observations of the productivity of pastures in large territories with the help of earth satellites can be made on the basis of optical vegetation indices obtained by combining readings of the MSS5, MSS6, and MSS7 spectral channels. As demonstrated in the course of an investigation (Maxwell, 1983), these channels are sensitive to a change in phytomass but are comparatively insensitive to the reflective properties of the soil and atmosphere. A normalized vegetation index is used to estimate the reserve of green mass of plants on pastures. Observations are made no less than three times during the growing season — late spring and early and late summer. The influence of drought on pasture productivity can also be demonstrated, having determined the seasonal dynamics of the relationship between living (green) and dead (brown) phytomass. This method of remote monitoring was tested in a study of pastures in Colorado (USA) and gave good results.

Photographs in the infrared portion of the spectrum with the use of IR emulsion have made it possible to differentiate various plant formations, as well as the parameters of the most important environmental factors with which vegetation dynamics are associated (Lebigre, 1983).

Of still greater interest for the recognition of vegetation and the estimation of phytomass is the equipment of Landsat-4 and Landsat-5 satellites especially adapted for thematic cartography (Landsat-D Thematic Mapper). This equipment can be used not only on satellites but also on other types of airborne apparatus (airplanes, helicopters). Revealing results have been obtained on the basis of the use of manual radiometers of the same type, intercepting spectral radiation in channels 3, 4, and 5. In this case the investigator stands on a slight eminence and holds the receiving part of the apparatus by hand, aiming the objective vertically downwards onto the vegetation. This method not only gives a tremendous savings of time but also ensures the procurement of more precise data on the reserve and structure of the phytomass than during the use of the generally excepted harvest technique (Hardiski, Klemas, and Daiber, 1983).

In addition to the passive, an active remote indication is possible. In particular, radar aerophotography is used. In this case a radar installed on an airplane is used to perform a pulsed irradiation of the locality on both sides of the flight line. The reflected signals are recorded on a cathode ray tube, after which the image is photographed on continuously moving photographic film. On the basis of these photographs, the vegetation can be interpreted and its productivity estimated (Kharin, 1975, 1980).

In recent years laser probing has been included in the arsenal of remote indication methods. This method is based on the study of the reflection of a laser beam by the plant cover. The laser probing of vegetation by its reflected brightness is currently used only to estimate certain parameters of the productivity of agricultural crops (Kanevskii et al., 1983), but it evidently may also find application for the monitoring of hay and pasture lands.

The remote estimation of the phytomass using existing equipment has evidently already approached the maximum possible precision. However, the further improvement of techniques and apparatus and the discovery of additional spectral channels may open even greater possibilities for the procurement of precise and diverse information of phytomass reserve, structure, and dynamics. This is of great significance for the transition to a global evaluation of ecosystems (Klemas and Hardiski, 1983).

PROGNOSIS OF ANTHROPOGENIC CHANGES IN VEGETATION

The changes in vegetation under the influence of pre-planned human impacts on ecosystems (creation of reservoirs, transfer of a portion of river runoff from some basins to others, drainage, irrigation, etc.), as well as other consequences of human activity (industrial pollution, recreation, livestock grazing, hay mowing, etc.), can be predicted on the basis of demonstrated patterns in the connection between individual types of plant communities or stages of their degradation and specific parameters of environmental conditions, taking into account the foreseeable change in these parameters in the future.

During prognostication account must be taken of the differing resistance of individual types of plant communities to anthropogenic impacts. Both direct (an analysis of real impacts, their experimental modeling) and indirect (proportional involvement of synanthropic species) methods can be used to estimate the level of anthropogenic impacts on any community. Reference and control regions in areas of the intensive exploitation of vegetation require geobotanical maps of the preagricultural, actual, and potential vegetation, as well as a series of prognostic maps reflecting the probable character of the plant cover that is compiled every 20-50 years on a given territory for various levels of anthropogenic impact (the current impact, two- to three-fold exceeding the current, and five- to seven-fold exceeding the current). Such maps, in particular, will be compiled by the Laboratory of Plant Ecology and Geobotany of the Institute of Plant and Animal Ecology, Urals Scientific Center, Academy of Sciences of the USSR, for the forest-steppe regions of the Cis-Ural Region. Prognostic geobotanical maps serve as an alarm signal, they warn of the real danger of catastrophic irreversible changes in the vegetation under anthropogenic pressures exceeding a permissible level and of the losses possible when the optimum regimen of exploitation of the plant cover is disregarded.

OBSERVATIONS OF THE CONDITION OF POPULATIONS OF RARE PLANTS

Environmental change under human influence, the transformation of habitats, and the destruction of the quasinatural plant cover result in the fractionation and numerical reduction of plant populations, the extinction of individual species, the general and local impoverishment of the flora, and the irreplaceable loss of the genetic resources of the plant world. Endemic, relic, as well as certain useful plants (decorative, medicinal, and food plants) are usually the most susceptible elements of regional floras.

In order to take timely measures to save rare and disappearing plants, the condition of their populations must be known. Observations of the populations of plant species most interesting and useful in a scientific and practical sense must be organized at certain control points. The density, population numbers, and spatial and age structure, population dynamics, and the response to anthropogenic effects must be considered. The age structure of populations is an especially valuable indicator: If it assumes a regressive character, this is a serious alarm signal.

We have organized such observations in the Urals for population of rare endemic milk vetches (*Astragalus helmii, A. clerceanus, A. karelinianus,* and *A. kungurensis*). These observations include the Kungur milk vetch, a critically threatened species represented by a single population on gypsum outcrops along the Sylva River. The numbers of this population have fluctuated from 300 to 500 plants in different years; a tendency for a decline in numbers has been noted in recent years (Gorchakovskii and Zueva, 1984).

In evaluating the condition of populations of rare plants one must bear in mind the characteristics of the life strategy of individual species. In his time, L. G. Ramenskii (1938) proposed that three categories of plants be distinguished: violent species, with a high competitive capacity, creating a special phytoenvironment, and tenaciously holding its territory; patient species, surviving due to their hardiness; and exploratory species, capable of rapidly occupying free space but easily displaced by other plants. Grime's (1979) categories of life strategies are similar to Ramenskii's categories. Research has shown that most Ural rocky mountain-steppe endemics are represented by species that rapidly colonize an exposed rocky substrate but do not withstand competition on the part of other herbaceous plants, especially sod grasses. Therefore, a regimen of moderate economic exploitation of the habitats of such endemics does more to assure their preservation than a regimen of absolute protection.

CONCLUSION

Anthropogenic impacts have now become a decisive factor in the formation and dynamics of ecosystems. The condition and dynamic tendencies of phytocenoses — the most important components of ecosystems — cannot be correctly evaluated without considering how they are influenced by man. This determines the need for a detailed study of the patterns of vegetation synanthropization and the development of methods for evaluating the level of the anthropogenic degradation of plant communities. Control of the process of the degradation of vegetation requires the availability of data on the condition and anthropogenic dynamics of plant communities in individual botanico-geographic regions so that urgent measures might be taken to save the treasures of the plant world at the most critical sites.

Global and regional botanical monitoring services and the detection of stresses are as necessary as the service for monitoring the condition of the atmosphere and the continental watershed. Botanical monitoring may be extradepartmental, exercising control over the exploitation of the resources of the plant world at a scale of the entire nation or large regions, and intradepartmental, conducting observations of the exploitation of plant resources within separate management units (tree farms, state and collective farms).

The organization of observations of the condition of the plant world is an urgent necessity. Meeting this challenge in the near future requires, firstly, the further development and improvement of the theoretical and technical bases of botanical monitoring as applied to individual types of vegetation and natural regions and, secondly, the training of cadres of specialists capable of monitoring the condition of the plant cover.

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