DESERT-PASTURE VEGETATION YIELD RECORDING USING PHOTOMETRIC METHOD

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Abstract

The paper presents the distant methods of determining the above-ground phytomass of pasture lands, based on its relationship with the spectral brightness coefficients. The relations between pasture productivity, presented by different crop varieties at different stages of the growing period, and the spectral brightness coefficient are shown on the basis of the obtained regressions.

The productivity recording of natural pasture lands is one of the difficult tasks on pasture farm because it is closely connected with the solution of such problems as choosing a plot, the number of plots allotted and recorded, their size, conformity of a plot itself, the method used for productivity recording.

The traditional cut-sample method is widely-used in geobotanical permanent establishments and under route examination. In spite of the fact that this method is widely used everywhere, it is characterized by subjectivism, causing systematical mistakes. The method of estimating pasture-productivity, based on the correlative relations of plant mass with their parameters (shrubs height, diameter etc.) has been offered recently. The given biometrical method excludes labour-consuming processes of cutting, drying, weighing cut samples, however, it has certain disadvantages, especially in recording shrub phytomass and half-shrub vegetation. It is due to the fact that shrub vegetation seems to change slightly in its habitus in different year. Thus, in favourable years the high productivity is not mainly connected with the shrub size, but with its foliage, which greatly influences the size of the whole above-ground phytomass.

Methods

A distance (photometrical) method for estimating the productivity of natural hayfields and pastures as well as crops, based on the reflective properties of vegetation covering, has been worked out and introduced [1].

The photometric method for determining the productivity of vegetation cover productivity is based on the relationship of plant-covering parameters (the thickness of plants distribution, the area of their leaf-surface, the amount of the above-ground plant mass) with the brightness coefficient of the “soil-vegetation” system. These characteristics of plant communities as well as the reflective soil properties form the optical properties of ecosystems on each photometrical plot.

A one-tube two-channel photoelectric photometer is used as a unit of the set together with standards, additional devices for its operating installation, and microammeter of M-194 type. The light stream, reflected from the studied object or from the standard, falls onto the glass with sprayed mirror covering, which divides it into two channels: 640-670 (red) and 700-750 nm (infra-red). The light energy is transformed into the electric one by photoelements and then it is registered with devices. The visual angle of the photometer is 35°. Dispenser of type MC-13 is used as a working standard. The height of photometer installation for grass and shrub desert-pasture vegetation is calculated in such a manner that the area of 1 m^2 should be in sight for the device. The photometric post is installed vertically so that the photometer object-glass should be situated right above the plot centre. The second observer took from 3 to 5 records per each channel and recorded the data in the corresponding graphs of the field photometric register. The spectral coefficients of the standard brightness were determined before the beginning and in the end of work.

The ratio value of brightness coefficients Knp is determined according to the formula:

$$Кпр = \frac{\frac{Мдик}{МдК}}{\frac{Мэик}{Мэк}} \times \beta$$

where (3 is the ratio of field standard brightness coefficient in two plots of the spectrum ($R_{эик}/R_{эк}$); $M_{дик}$, $M_{дк}$ is the average value obtained from the individual plot records; $M_{эик}$, $M_{эк}$ is the average value obtained from the standard records.

The graduated curves, connecting these two indications, were built up on the basis of spectral brightness coefficients for each association and above-ground plant mass, determined by cut-sample method. The values of the vegetation cover productivity were put along the y-axis, while Knp was put along the x-axis. The above-ground photometric shooting was conducted using the developed methods [2.3]. All the equipment used in air-photometry was appropriate for measuring the coefficients of the desert-pasture vegetation brightness in the two spectrum parts as well as for registrating the measurements in the digital form. The photometer signal registration was carried out by means of potentiometers. The whole block of measuring instruments was installed on the board of helicopter Mi-8. The obtained spectral data (Knp) were compared with the developed graduated scale of dry desert-pasture vegetation phytomass and the corresponding Knpindicator.

Research Outcomes

Let’s consider the results of the above-ground photometric observations, obtained in the field period from 1997 to 1998.

The above-ground photometric observations were organized on the permanent trial plots of the experimental sandy tract testing area in Sariesik-Atirau. The trial plots were introduced by nine associations. The observations were held in different growing periods. The brief characteristic of the associations allows to judge about the phytocenotic variety and location of the studied objects.

The Ephemer - whiteland wormwood - eurotia association (Kracheninnikovia ceratoides-Artemisia terrae albae- Carex physodes) occupies the slopes of north-eastern expositions of sandy hillocks and ranges, and interhillock lowering as well. This lowerings have more compressed surface of the soil and serves as the place of flowing down melted waters. The living forms of the Ephemer - whiteland - wormwood - eurotia association are diverse, varying from ephemeroidal polycarpic and monocarpic grassy plants to desert trees represented by cenopopulation of white Saxaul.

The general grey-white colour is created due to the background plants such as eurotia grey (Kracheninnikovia Ceratoids), artemisia, and only sometimes groundsel shrubs.

The efemers and efemeroids, such Carex physodes, Meniocus linifolius, Hypecoum parviflorum, Lappula semiglabra, Arnebia decumbens vegetate a lot in spring. Shrubs of white Saxaul are destinguished in the upper thinned tier.

The basis of herbage consists of Eurotia grey and whiteground wormwood which constitute 70-80 % of the whole yield in abundance and weight.

Eurotia grey (Kracheninnikovia Ceratoides), a xerophil half-shrub 120 cm height, predominates in the association. The spring growing of Eurotia grey begins in April, vegetates intensively in May and blossoms in June-July.

The first estrange of the above-ground vegetation mass and measurements of the spectral characteristics were carried out in the third decade of May in 1997. A rather steep curve was typical of the ephemer-whiteland-wormwood-eurotia association in this period which is explained by the increase in the mass of wormwood and eurotia grey ratoides, as well as by the plenty of ephemers especially swollen-hollow carex. The fluctuations in the spectral brightness coefficients are within 1.21-2.25 (figure 1). A tight relation of yields with spectral coefficients is noticed, which is confirmed by the determination coefficients (R^2=0.927, R^2=0.759). To specify the regressions of the previous observations and to receive new data, the measurements were carried out the following year and the curves having little differences with the previous year. The fluctations in spectral characteristics (the third decade in May) are within 1.17-2.01 (figure 2).

The observations conducted in the second decade of June (year 1998) reflect slightly another picture. The crop of association is composed mainly of eurotia grey and wormwood. While eurotia grey continues to vegetate, a part of wormwood leaves has fallen down and generative offsprings have already formed. The main ephemers, composing the association, were in the fruiting phase, drying out and influenced the spectral characteristics very little. The general aspect has changed. The phenological characteristics resulted in changing the spectral characteristics.

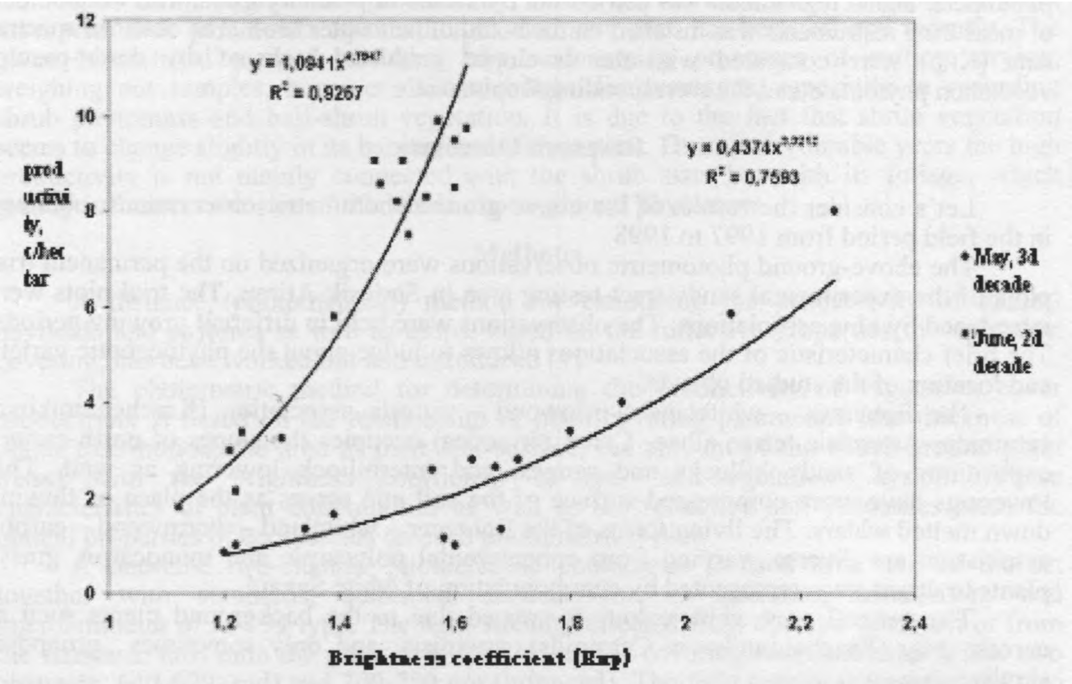

Fig. 1. The relationship between the productivity (dry mass) of ephemer-whiteiand-wormwood eurotia association (Kracheninnikovia ceratoides Artemisia terrae albae - Carex physodes) and the spectral brightness coefficient (Knp) on the callendar observation terms (1997)

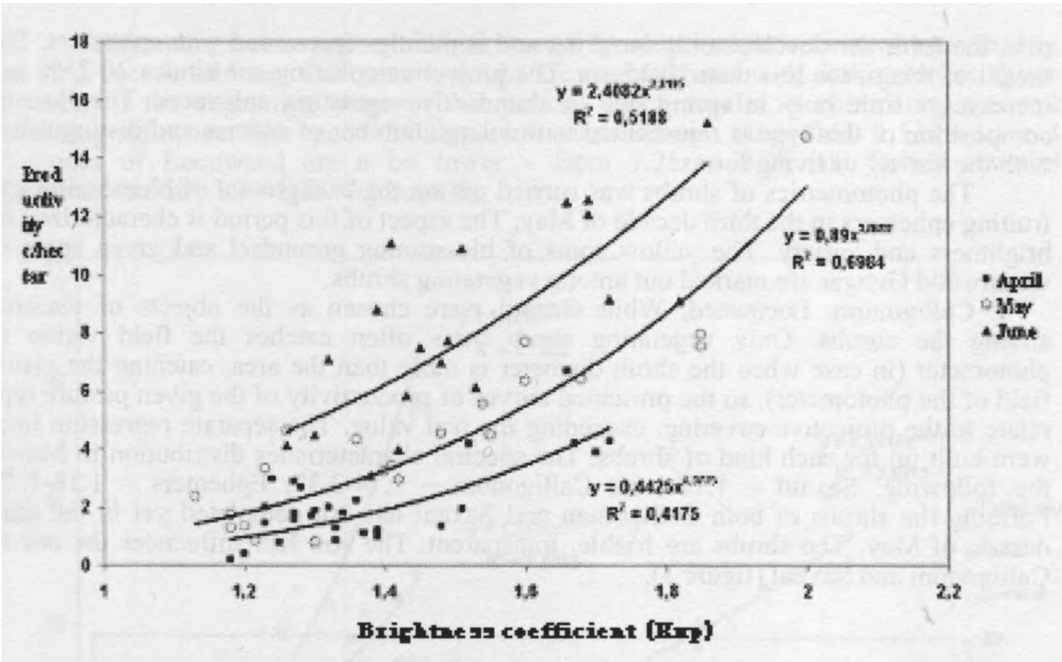

Fig. 2. The relationship between the productivity (dry phytomass) of the ephemer-whiteland-wormwood-eurotia association (Kracheninnikovia ceratoides Artemisia terrae albae - Carex physodes) and the spectral brightness coefficient (Kpr) on the calendar terms of observations (1998)

The decrease in spectral brightness coefficient is observed under the increased productivity. The relationship pattern between the productivity and the spectral brightness coefficients is maintained, which is confirmed with the appropriate equations (figures 1,2).

The productivity curves in the first and second decades of July are identical for both 1997 and 1998. The ephemers fallen out from the herbage, exposed the soil spots. Approximately 70% of whiteland wormwood leaves fell down, but in case of eurotia only the lower leaves fell down and the transition into the budding phase was noticed. The spectral characteristics range is within 1.11-1.45 (in 1997) and 1.20-1.87 (in 1998).

The highest Knp value for the ephemer-whiteland-wormwood-eurotia association (Kracheninnikovia ceratoides Artemisia terrae albae - Carex physodes) is noticed in May-June. The gradual decrease in Knp happens in July, but the yields increase at the same time. The average Knp values are equal to 1.43 and 1.35 in this period, and the yields are 4.5-6.41 c/hectare respectively. The increase in yields proceeds until the summer drying out of dominants.

The Ephemer-shrub association (Calligonum aphyllum + Astragalus paucijogus + Atraphaxis spinosa - Haloxylon persicum - Carex physodes) is mainly timed to loosened tops of sandy hillocks, and ranges, and slopes of eastern expositions.

White saxaul, different Calligonum varieties, little-pair locoweed, goat’s wheat predominate in this association.

Three or sometimes four tiers are marked in the vegetation cover. The first tier consists of white Saxaul and Calligonum reaching the height of from 1.0 to 2.5 meters. Calligonum and Locoweed are sometimes situated in the second tier; the third tier is represented with goat’s wheat and Eurotia grey and other perennials and annuals. As a rule, the forth tier develops only in spring and is mainly represented with ephemers. The height of this tier is less than 10-15 cm. The projective covering constitutes 20-25% and increases a little only in spring due to abundantly vegetating ephemers. The floristic composition of this type is represented with a large number of species and distinguished with the variety of living forms.

The photometries of shrubs was carried out on the background of blossoming and fruiting ephemers in the third decade of May. The aspect of this period is characterized by brightness and variety. The yellow spots of blossoming groundsel and green spots of wormwood Gungar are marked out among vegetating shrubs.

Calligonum, Locoweed, White Saxaul were chosen as the objects of research among the shrubs. Only vegetating shrub mass often catches the field vision of photometer (in case when the shrub diameter is more than the area, catching the vision field of the photometer), so the presented curves of productivity of the given pasture type relate to the projective covering, exceeding the real value. The separate regression lines were built up for each kind of shrubs. The spectral characteristics distribution in May is the following: Saxaul - 1.17-1.66, Calligonum - 1.74-2.32, Ephemers - 1.18-1.27. Forming the shrubs of both Calligonum and Saxaul has not completed yet in the third decade of May. The shrubs are friable, transparent. The soil Kpr influences the one of Calligonum and Saxaul (figure 3).

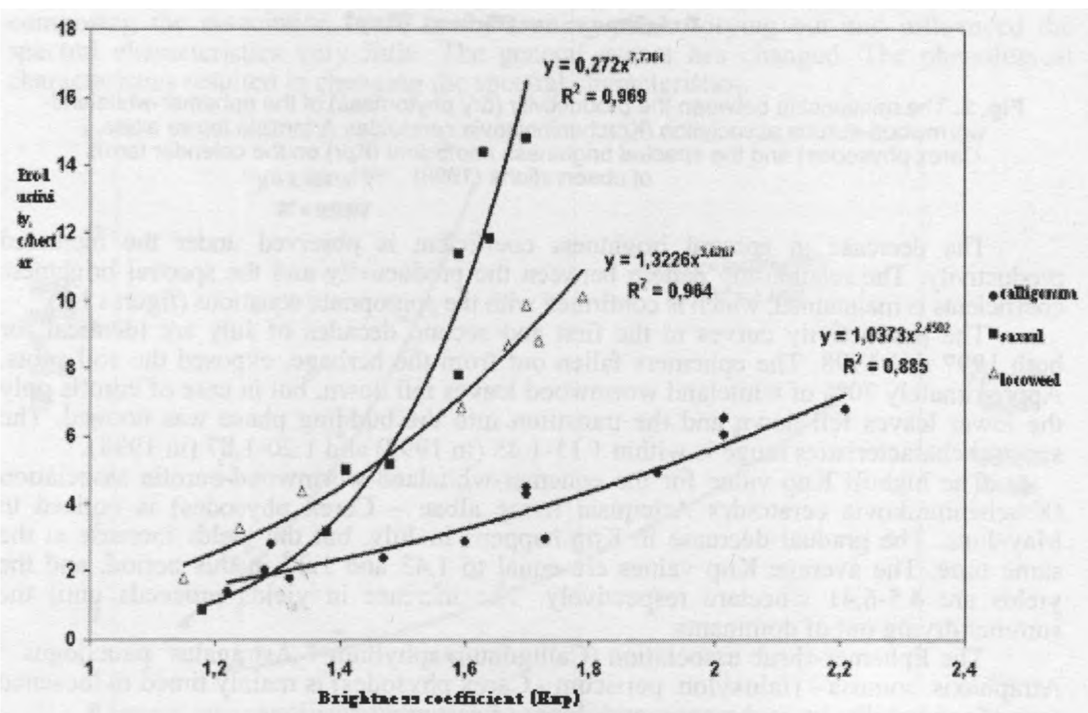

Fig. 3. The relationship between the productivity (dry mass) of the ephemer-shrub association (Calligonum aphyllum + Astragalus paucijogus + Atraphaxis spinosa - Haloxylon persicum - Carex physodes) and the spectral brightness coefficient (Knp) on the calendar observation terms (the third decade of May, 1997 year)

Calligonum, Locoweed and White Saxaul blossom, while ephemers bear fruit in the first decade of June. Calligonum shrubs are characterized with dark greenery dense location of the vegetating mass in this period, which results in eliminating the soil screening influence. The spectral Calligonum characteristics range from 1.53 to 3.1 and the ones of Locoweed are a bit lower - from 1.25 to 2.88 and Saxaul spectral characteristics are 1.16-1.78 (figures 4,5).

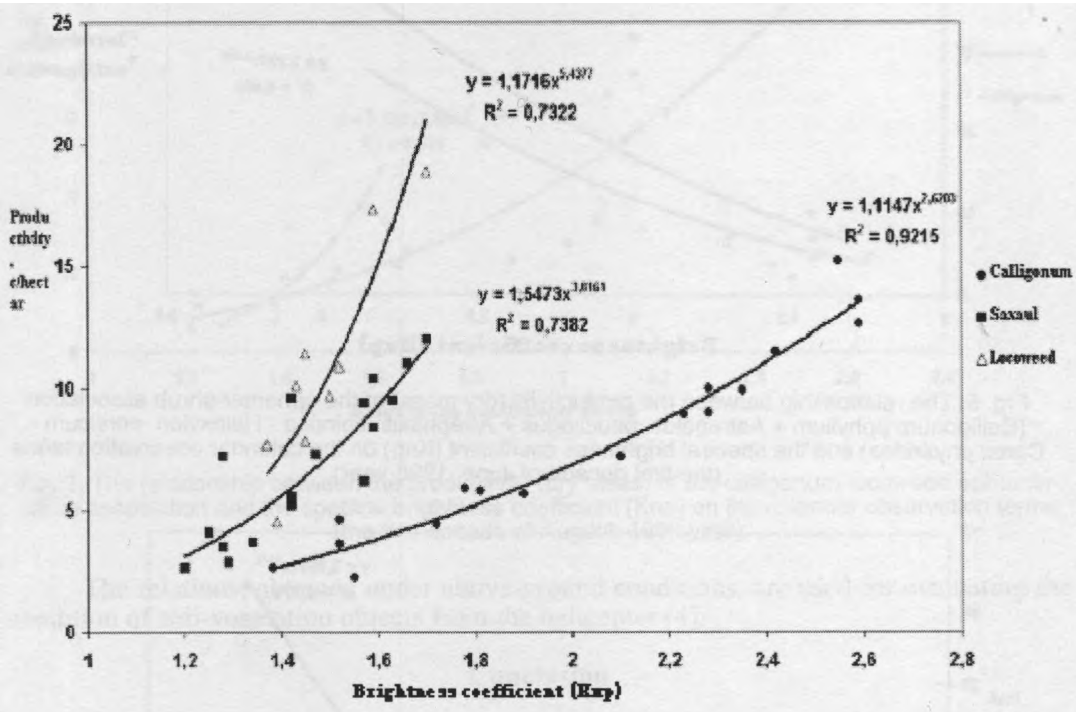

Fig. 4. The relationship between the productivity (dry mass) of the ephemer-shrub association (Calligonum aphyllum + Astragalus paucijogus + Atraphaxis spinosa - Haloxylon persicum - Carex physodes) and the spectral brightness coefficient (Knp) on the calendar observation terms (the first decade of June, 1997 year)

The shrubs fruit and lose a part of their vegetating mass in the first decade of July; the ephemeral tier destroys and large soil plots become bare. The spectral characteristics decrease and take the following values: 1.02-2.37 for Calligonum, 1.0-1.79 for Locoweed, 1.08-1.60 for Saxaul (figure 6). The revealed relation of productivity and spectral coefficients is maintained constant, though the determination coefficients are objectively lower, excluding Calligonum.

The green assimilation Calligonum offspring and the green-bluish ones of Locoweed are getting rougher in August. The aspect gets grey tints, and only the shrubs of transparent salt grass stand out as green spots. In spite of late-summer aspect, the relationship of parameters revealed is maintained constant (figure 7).

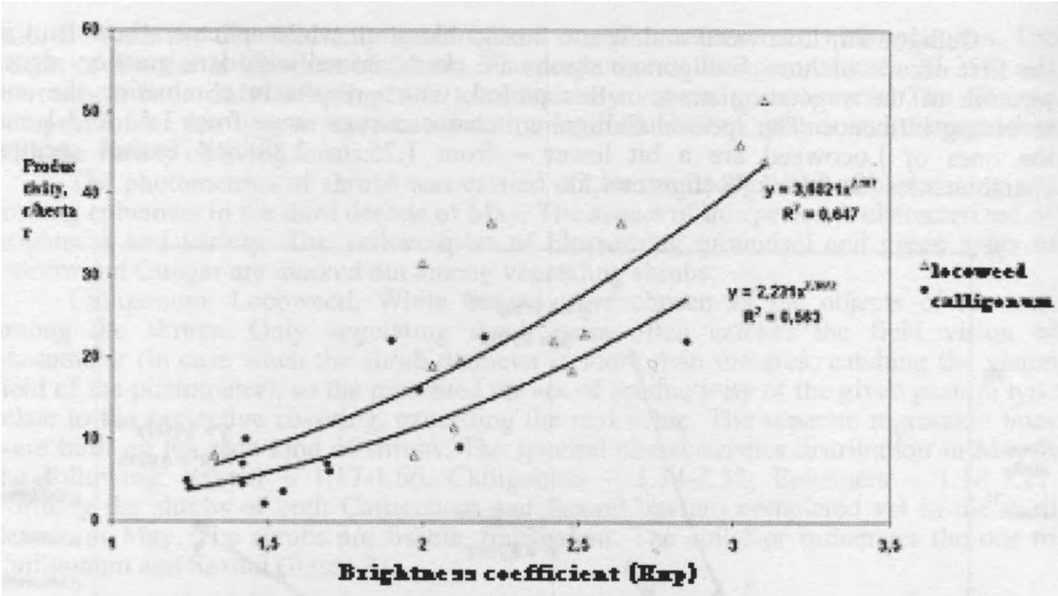

Fig. 5. The relationship between the productivity (dry mass) of the ephemer-shrub association (Calligonum aphyllum + Astragalus paucijogus + Atraphaxis spinosa - Haloxylon persicum - Carex physodes) and the spectral brightness coefficient (Knp) on the calendar observation terms (the first decade of June, 1998 year)

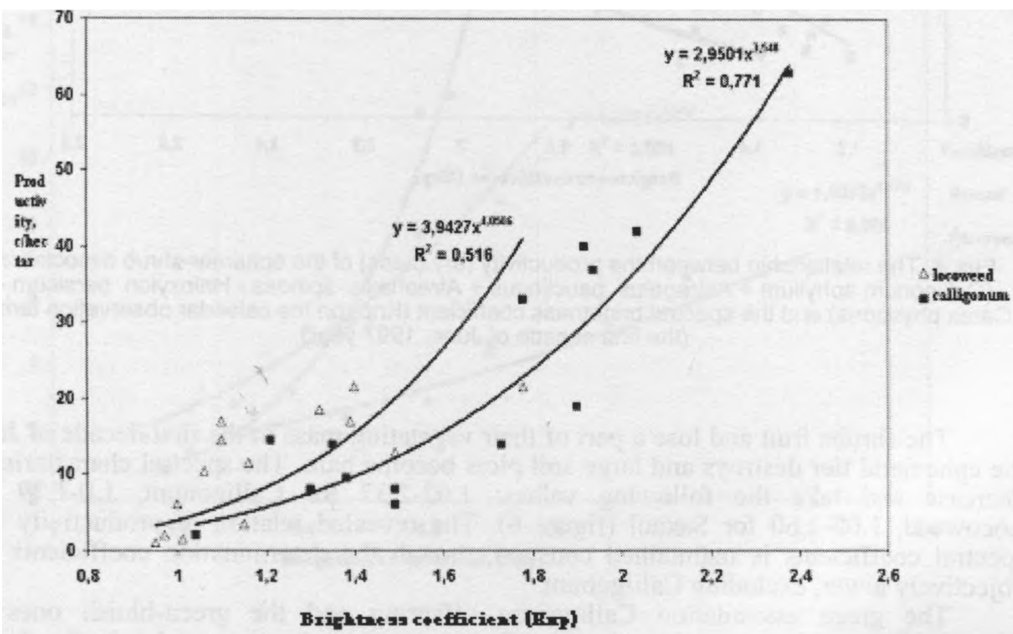

Fig. 6. The relationship between the productivity (dry mass) of the ephemer-shrub association (Calligonum aphyllum + Astragalus paucijogus + Atraphaxis spinosa - Haloxylon persicum - Carex physodes) and the spectral brightness coefficient (Knp) on the calendar observation terms (the first decade of July, 1998)

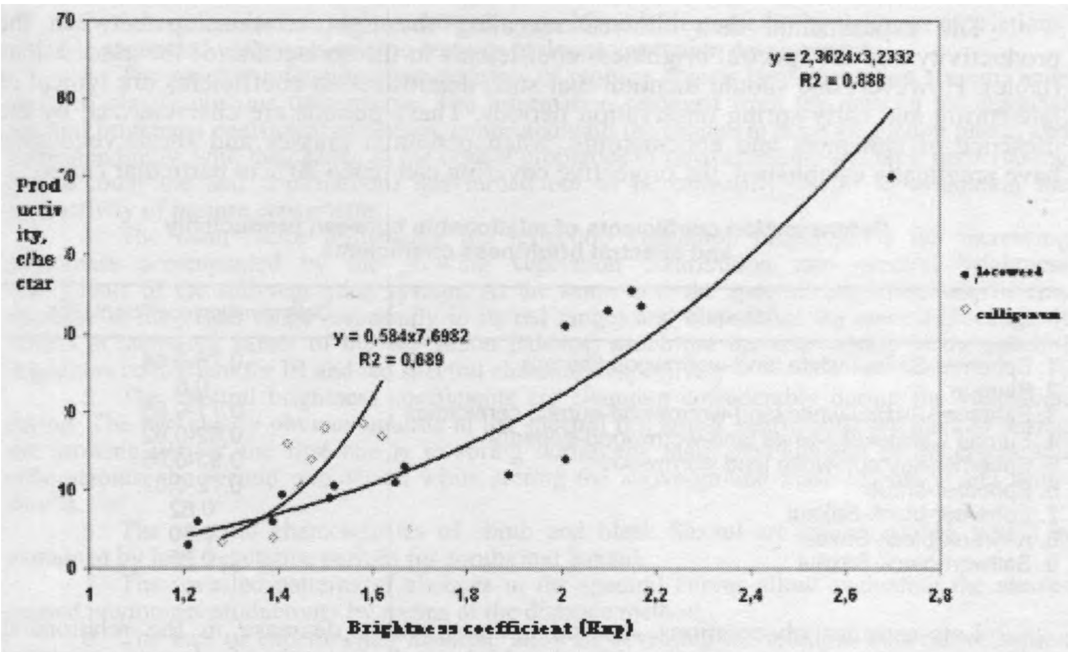

Fig. 7. The relationship between the productivity (dry mass) of the calligonum-locoweed-ephemer-shrub association and the spectral brightness coefficient (Knp) on the calendar observation terms (the first decade of August, 1998 year)

The relations, obtained under above-ground conditions, are used for evaluating the condition of soil-vegetation objects from the helicopter [4].

Conclusion

The obtained regression lines visually reflect the changes in the spectral brightness coefficient during the vegetation period.

The spectral reflection characteristics of probing objects ("soil-vegetation" system) reveal impressive seasonal changes. The information retrieved from the data on the temporary spectral brightness coefficient dynamics connected with changes the plant vegetation phases, and correspondingly, with changes in the optical phytoelement properties and their mass, taking into account the soil contribution, appeared to be especially useful in evaluating the productivity of pasture ecosystems (4).

During the period from the vegetation beginning to blossoming when the optical leaf and stem characteristics change slightly, the main factor influencing the reflection vegetation properties is the increasing phytomass, accompanied by the growing vegetation contribution into the spectral brightness coefficient of the "soil-vegetation system". At the same time the spectral brightness coefficient decreases in the visual range (especially in its red range) and increases in the nearest IK-range, which results in increased values of vegetation indexes. The latter represents the relationship of the spectral brightness coefficient for IK- and red spectral channels, respectively.

The reverse change in the spectral brightness coefficients and the vegetation indexes occurs in the period of yellowing the above-ground phytomass. Different variations in spectral characteristics are possible during flowering.

The experimental data allowed revealing the tight relationship between the productivity and the spectral brightness coefficients in the connection of the associations (table). However, one should mention that such determination coefficients are typical of late-spring and early-spring observation periods. These periods are characterized by the presence of ephemers and ephemeroids, when perennial grasses and shrub vegetation have practically established, the projective covering can reach 80% in particular cases.

Determination coefficients of relationship between productivity and spectral brightness coefficients

Association	Determination coefficient (R^2)
1. Ephemer-Saxaul-white land-wormwood keyreuk	0,75-0,84
2. Biurgun	0,5
3. Ephemer-Saxaul-white land-wormwood-eurotia ceratoidies	0,71-0,85
4. Eurotia Ceratoidies-white land-wormwood-ephedra	0,82-0,92
5. Ephemer-keyreuk-white land wormwood	0,93-0,95
6. Ephemer-shrub	0,72-0,87
7. Ephemer-black-Saxaul	0,82
8. Keyreuk-black-Saxaul	0,80
9. Saltwort-black-Saxaul	0,85

Late-summer observations showed a considerable decrease in the relationship tightness, which is connected with the biological features of desert vegetation development. At the same time the experimental data allowed to reveal the optimal time for carrying out photometric observations. Plant communities and their edificators are characterized by different reflection properties.

The spectral brightness coefficients change greatly during the vegetation period that is due to the changes in the phonological state of vegetation as well as increasing dynamics of vegetative mass. The two obvious upturns in the spectral brightness coefficient are noticed during the vegetative period: the first - in spring during the ephemers and ephemeroids mass development; the second - during accumulation of the above-ground mass in shrubs and semi-shrubs.

The spectral characteristics of shrub and black Saxaul are mainly stable, which is explained by long vegetative periods for shrubs and Saxaul. The revealed relations between the productivity and the spectral brightness coefficients are confirmed by the corresponding regressions with rather high determination coefficients.

The patterns revealed and regressions obtained allow determining the above-ground phytomass statistically for certain.

At present the restraining factor in developing distance methods for evaluating the soil-vegetation object condition is the shortage in experimental material, allowing revealing the relations between the reflexion spectra and biometric characteristics. It is necessary to continue the research of spectral characteristics of vegetation and soil coverage by both above-ground and airspace methods.

Deductions

1. The experimental data allowed establishing the relation between production and spectral brightness coefficients in the context of the main associations for late-spring and early-summer observation periods, which is confirmed by the appropriate regression equations and determination coefficients. The optimal time periods for carrying out air photometric observations have been revealed.

2. Late-summer observations showed a considerable decrease in the tightness of relations, which is connected with the biometric features of desert vegetation development.

3. The spectral reflection characteristics of probing objects (soil-vegetation system) have revealed clearly obvious time course. The information retrieved from the data on the seasonal spectral brightness coefficient dynamics, connected with the change in plant vegetation phase, and correspondingly, with the change in the optical properties of phytoelements and their mass (taking into account the soil contribution) has turned out to be especially useful in evaluating the productivity of pasture ecosystems.

4. The main factor influencing the reflection vegetation properties is the increasing phytomass accompanied by the growing vegetation contribution into spectral brightness coefficients of the soil-vegetation system. At the same time the spectral brightness coefficients decrease in the visual range (especially in its red range) and increase in the nearest IR-range. It results in increased values of the vegetation indexes, which are the relationship of the spectral brightness coefficient for IR and red spectral channels, respectively.

5. The spectral brightness coefficients are changing considerably during the vegetation period. The two clearly obvious upturns in the spectral brightness coefficients are marked during the growing period: the first one is in spring during the mass development of ephemers and ephemeroids, the second one occurs while storing the above-ground mass of shrubs and semi-shrubs.

6. The spectral characteristics of shrub and black Saxaul are mainly stable, which is explained by long vegetative periods for shrubs and Saxaul.

7. The revealed patterns of changes in the spectral curves allow evaluating the above-ground phytomass productivity by means of the distance method.

8. The lack of experimental material, allowing revealing the relations between reflection spectra and biometric indications is still a restraining factor in developing the distance methods for evaluating the soil-vegetation object condition. Thus, it is necessary to continue studying the spectral characteristics of vegetation and soil coverage using both above-ground and airspace methods.

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Summary

The distance methods for determining the above-ground pasture-land phytomass based on its relation with the spectral brightness coefficients are discussed. The obtained regressions rather high determination coefficients reveal the possibility of using photometric method in evaluating pasture productivity.