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River basin soil–vegetation condition assessment applying mathematic simulation methods

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INTRODUCTION

Soil fertility and vegetation productivity are essential ecologic-economic parameters, which define ecosystem structure and functioning.

Vegetation condition is closely connected to the peculiarities of soil cover. Soil is very important for terrestrial ecosystems, because it unites all the rest components into a single functioning system.

INTRODUCTION

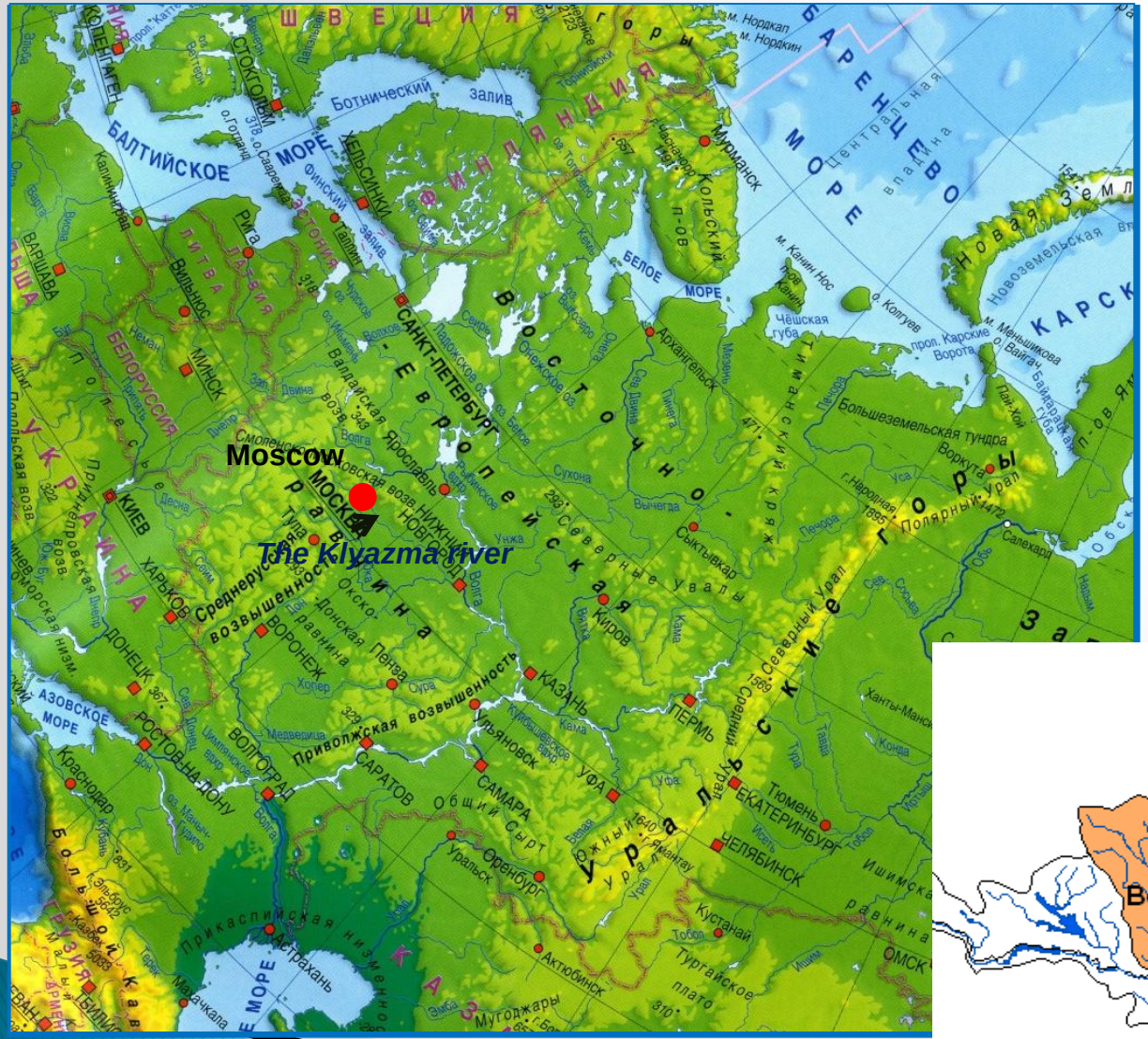
Generally a set of indicators is used to characterize each component of any ecosystem.

Productivity is a very important characteristic of vegetation, which is used to evaluate ecosystem stability. ***Appraisal*** and ***soil-ecologic index*** (SEI takes into account agrochemical properties of soil, soil density, mechanical structure, agroclimatic parameters) are often used to asses soil condition.

In our point of view ***there are not enough integrated indices,*** which characterize soil and vegetation as a unified system.

Besides, ***the application of mathematic simulation methods*** is not sufficiently developed. Though these methods can be used to assess “phytocenosis-soil” system and the influence of land use change on this system.

OBJECTS AND METHODS



Basin approach has been applied in the research.

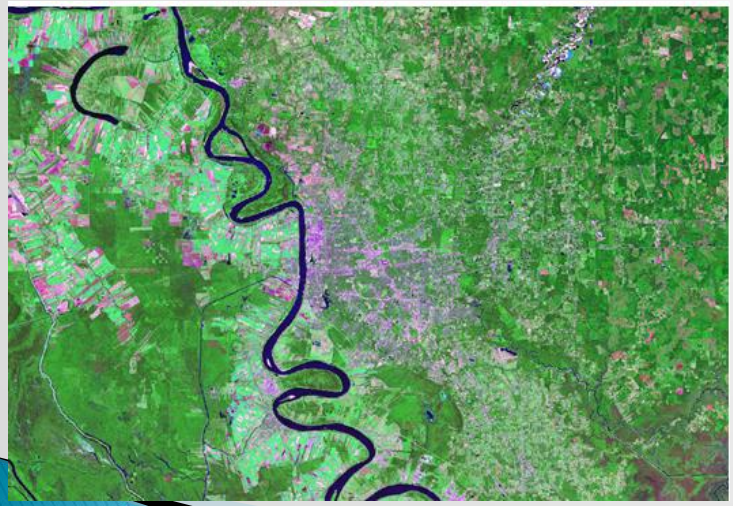
We have chosen ***small rivers basins of the Klyazma river*** as our research objects.

They are situated in the central part of the Russian plain.

OBJECTS AND METHODS

The analysis was carried out applying:

- integrated characteristics of ecosystems functioning
- space images processing
- mathematic simulation methods
- GIS technologies.



SOIL-PRODUCTIVE POTENTIAL

Indicator of "soil-productive potential" (SPP) determines nature and nature-anthropogenic ecosystem ability to reproduce product (or phytomass) in certain soil-bioclimatic conditions during a long-term period.

SOIL-PRODUCTIVE POTENTIAL

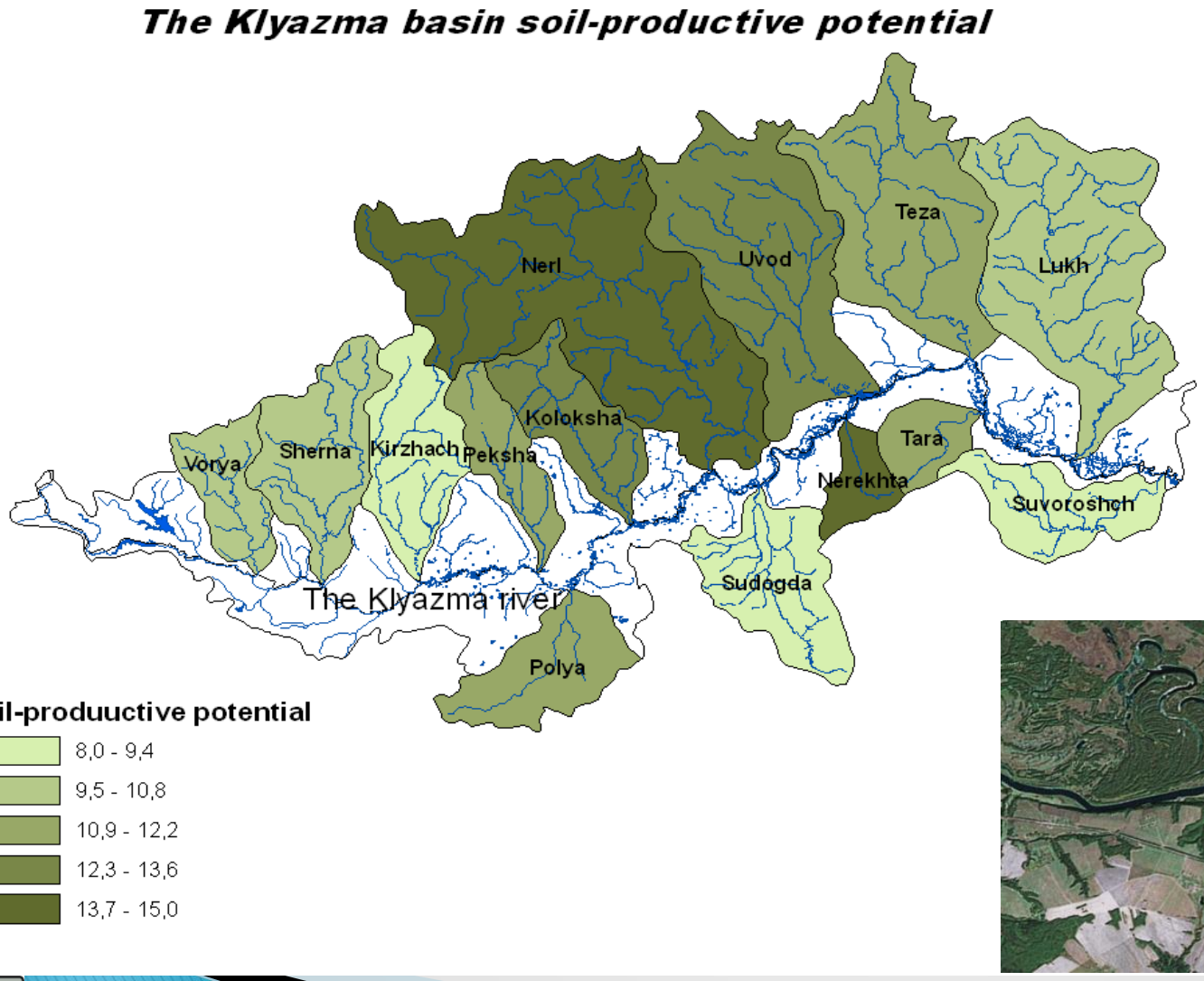
Soil-productive potential (SPP) characterizes ecosystem resource numerically and averages the following parameters:

- ***specific phytomass reserve*** (natural overground and underground plant organs summation is considered in the indices of absolutely dry mass, t/hectare);
- ***specific productivity*** (phytomass augmentation per unit area a year);
- ***natural soil fertility*** (humus content was taken as its characteristics, %);
- ***grain crop capacity*** (grain crops capacity is taken into account, centner/hectare);
- ***bio-climatic parameters*** (integrated index, including the sum of biologically active temperatures and precipitation-evaporation ratio);
- ***soil-ecologic index*** (SEI takes into account agrochemical properties of soil (pH, phosphorus, potassium, humus content), soil density, mechanical structure, agroclimatic parameters))

SOIL-PRODUCTIVE POTENTIAL

Soil-productive potential	Assessing parameters
Natural ecosystems (without agrocenosis)	*1. Specific phytomass reserve* *2. Specific productivity* *3. Natural soil fertility* *4. Bio-climatic parameters*
River basin ecosystems as a whole (with agrocenosis)	*1. Specific phytomass reserve* *2. Specific productivity* *3.Grain crops capacity* *4. Soil-ecologic index (SEI)*

SOIL-PRODUCTIVE POTENTIAL



Comparative characteristic of the Klyazma tributes SPP

River basin	Phytomass reserve , t 10^3	Basine specific phytomass reserve , t/hectare	Specific phytomass reserve of natural ecosystem, t/hectare	Score	Productivity, t 10^3/year	Basine specific productivity t/hectare year	Specific productivity of natural ecoststems., t/hectare	Score	SEI	Score	Grain crop capacity , centner/hectare	Score	SPP
Sherna	21195	112.4	177.6	3	1359.1	7.4	11.39	4	46.3	2	13.3	1	10
Peksha	11264	105.8	156.1	3	856.7	8.04	11.87	5	46.4	2	15.9	2	12
Koloksha	7199	50.5	113.3	1	846.7	5.93	13.33	2	61.7	5	23.4	5	13
Nerl	73260	109.6	190.55	3	3252.73	4.87	8.46	1	65.5	5	23.6	5	14
Uvod	50795	133.7	210.18	4	2571.68	6.77	10.64	3	53.5	3	18.8	3	13
Lukh	30314	69.9	74.94	1	3655.36	8.41	9.03	5	49.0	2	16.31	2	10
Suvoroshch	11433	82.3	138.61	2	894.87	6.44	10.85	3	47.8	2	13.8	1	8
Tara	11586	172.4	207.18	5	512.39	7.62	9.16	4	48.7	2	13.9	1	12
Nerekhta	7984	143.4	181.94	4	441.76	7.93	10.07	5	52.3	3	17.6	3	15
Kirzhach	25725	145.5	242.9	4	1026.3	5.81	9.69	2	50.1	2	14.3	1	9
Sudogda	23045	120.3	194.58	3	1198.84	6.26	10.12	3	41.6	1	13.0	1	8
Teza	47707	135.8	212.11	4	2353.84	6.7	10.47	3	41.0	1	21.2	4	12
Vorya	9499	93.7	180.86	2	463.59	4.57	8.83	1	52.0	3	21.2	4	10
Polya	16727	107.7	151.7	3	855.63	5.51	7.76	2	52.0	3	21.2	4	12
Klyazma	443428	106.5	161.9	3	25905.19	6.22	9.46	3	52.0	3	21.2	4	13

Permanent model of phytoproductivity distribution within the Klyazma basin

Nonlinear logistic growth function, used in population biology, became the model basis.

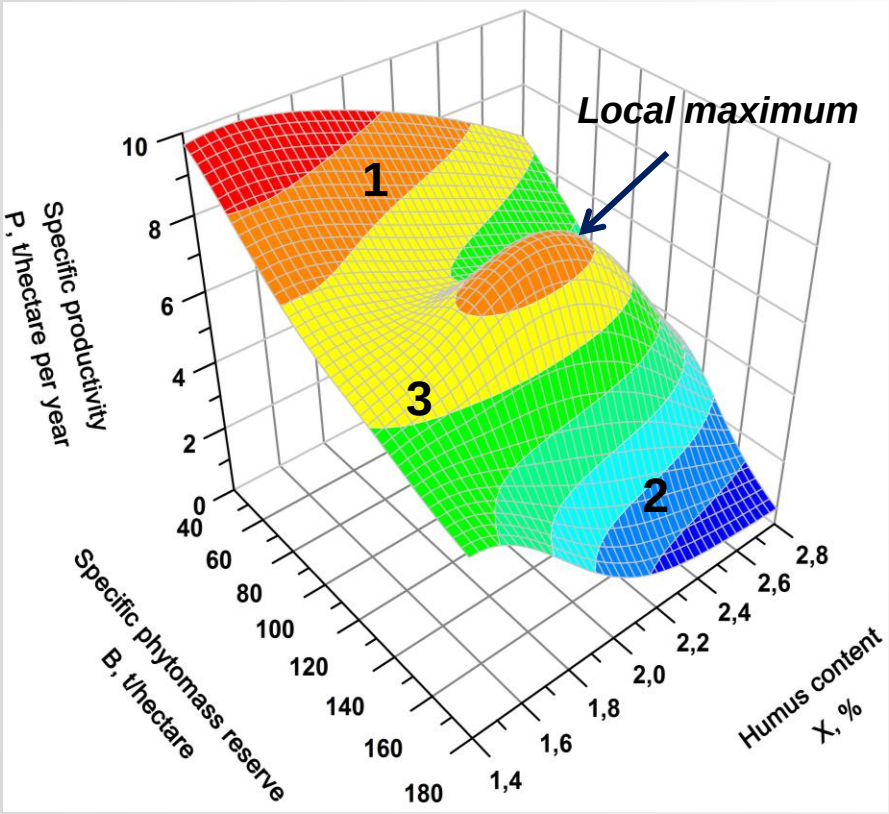
According to the growth function productivity P, t/(hectar·year)) is determined by the following equation :

$$P = rB\left(1 - \frac{B}{K}\right)$$

with
r – phytomass gain intensity rate, year^{-1};
B – phytomass, t/hectar;
K – max value of phytomass for phytocenosis (ecosystem capacity), t/hectar.

Phytoproductivity distribution model in the Klyazma basin is executed in the algorithm on nonlinear approximation by the method of minimal squares in “Mathcad”.

Permanent model of phytoproductivity distribution within the Klyazma basin



Basin phytoproductivity distribution

The diagram reflects the areas of possible permanent conditions of "phytocenosis-soil" system within the Klyazma basin :

1.Basins with prevailing meadow phytocenosis. They are characterized by low phytomass (less then 94 t/hectare) and maximum phytoproductivity. Productivity is gradually decreasing with the increase of humus content.

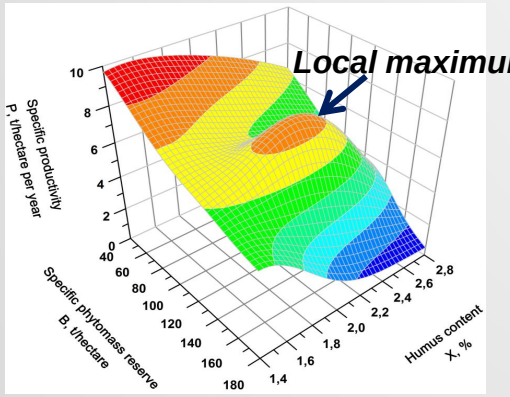
2.Basins with prevailing forest phytocenosis. They are characterized by maximum phytomass (over 146 t/hectare). Here phytoproductivity is dramatically decreasing with the increase humus content.

3.Basins with intermediary position regarding phytomass. But here phytoproductivity can have local maximums. They are connected to a certain ratio of forest and meadow phytocenosis.

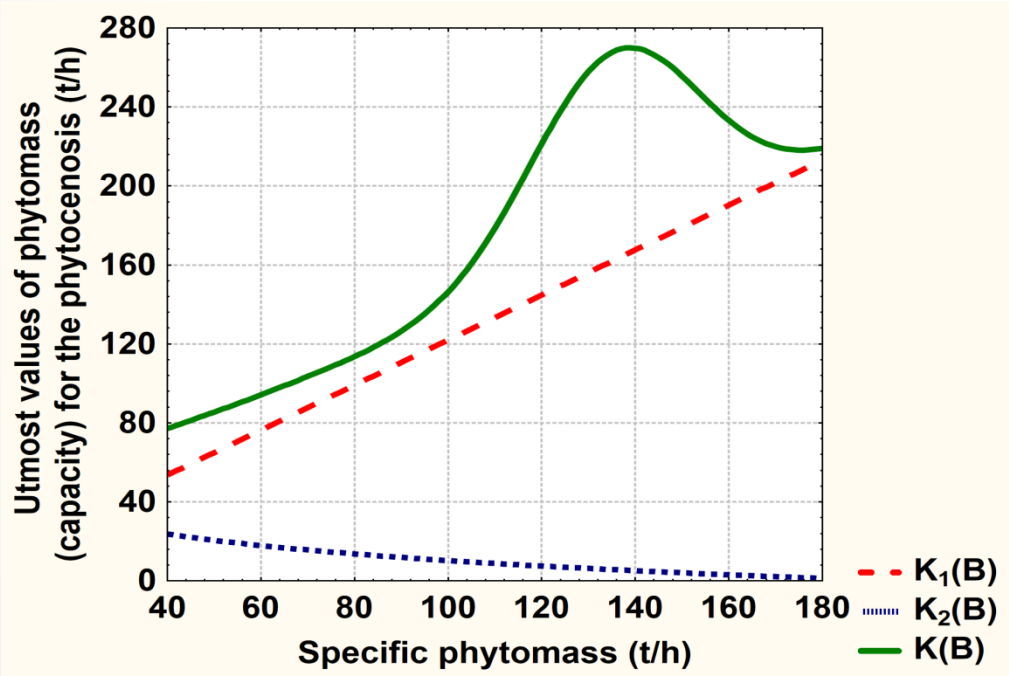
Permanent model of phytoproductivity distribution within the Klyazma basin

Ecosystem productivity is defined not only by vegetation photosynthesis activity but also by the area ratio of forest and meadow phytocenosis.

We explain the local maximum by ***synergetic effect***. In this case, utmost values of phytomass for the whole area are higher then just a sum of utmost values of phytomass for the forest and meadow phytocenosis.



Basin phyto-productivity distribution



Synergetic effect (for humus content of 2,29%)

K_1 - *utmost values of phytomass (capacity) for the forest phytocenosis, (t/h)*

K_2 - *utmost values of phytomass (capacity) for the meadow phytocenosis, (t/h)*

K - *utmost values of phytomass (capacity) for the whole area, (t/h)*

$$K > K_1 + K_2$$

Permanent model of phytoproductivity distribution within the Klyazma basin

One of the most probable permanent condition of “phytocenosis-soil” system within the Klyazma basin is located in the area with ***specific phytomass value of B = 133,56 t/h and humus content of 2,29%.***

Such condition is achieved at ***forest and meadow phytocenosis ratio of 7:1.***

Using our mathematical model, we can forecast, that in case of the lack of anthropogenic impact the ratio of forest and meadow phytocenosis will rank 7:1.

This ratio corresponds to the location of the region in the southern taiga and it is approved by the intensive overgrowing of the abandoned agricultural lands.

CONCLUSION

Thus, to assess soil-vegetation resources of the area we offer to use soil-productive potential index.

Mathematic simulation methods help to forecast conditions of ecosystem under various changes of land use structure. Nowadays overgrowing of the abandoned agricultural lands is very actual for the Russian Federation. Simulation results demonstrate that natural ratio of forest and meadow phytocenosis for the area will restore during agricultural overgrowing.

Thanks for you attention!

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