MONITORING OF CLIMATE-RELATED COMPONENT OF DESERTIFICATION

A.N.Zolotokrylin
Institute of Geography, RAS, Moscow, Russian Federation
(e-mail:zgoldfinch@mtu-net.ru)

The main purpose of the investigation was to study the mechanisms and provide explanation for climate-related desertification expansion.

Desertification needs two ingredients: aridization (climate-related desertification) and degradation

Areas: dry lands of Northern Eurasia and Northern Africa.

The hypothesis: Climate-related desertification is a result of interaction between regional processes of degradation of dry lands, with *positive* and ***negative feedbacks*** related to albedo and precipitation changes.

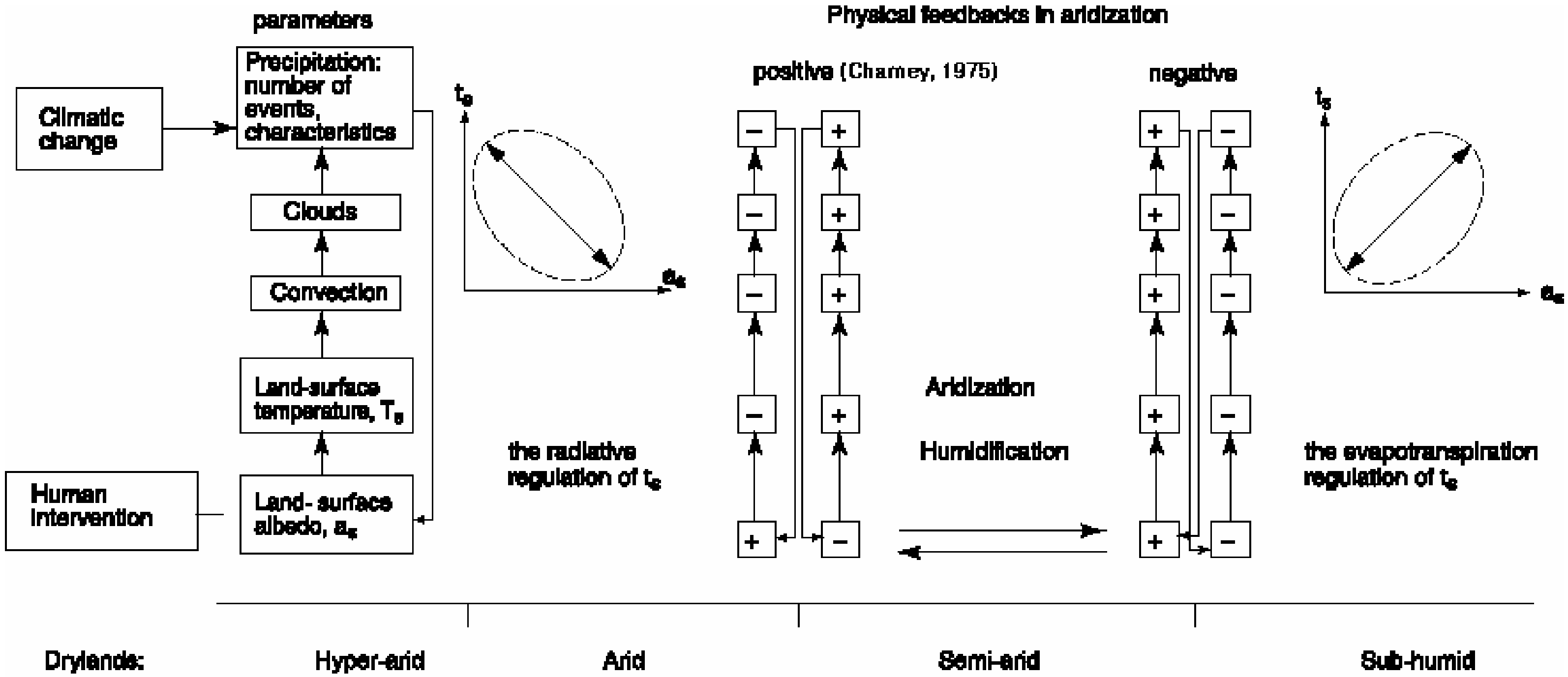
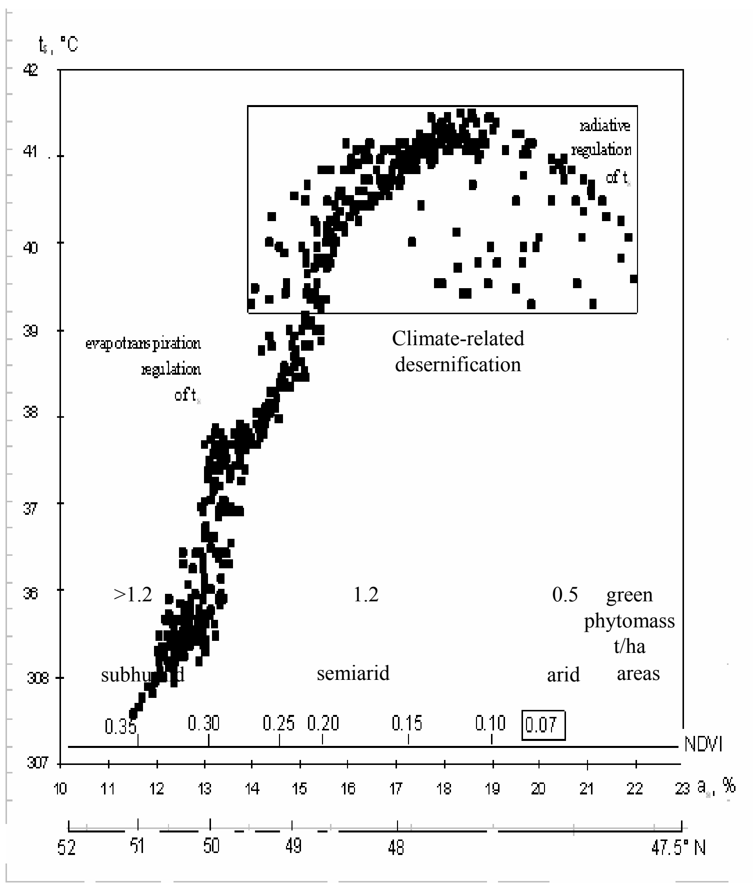


Fig.1. Hypothesis for albedo-precipitation feedbacks in aridization of dry-lands.

Climate-related desertification is maintained by a **positive** feedback in regional climatic system dominated by radiative regulation of surface temperature. Expansion of positive feedback is blocked by ***negative*** one dominated by evapotranspiration regulation of surface temperature. Switch from **positive** feedback to the **negative** one is predetermined by the change of heat transfer between surface and atmosphere, if the sensitive heat flux increases. This mechanism takes place in case of simultaneous increase of albedo and surface temperature. The threshold value of green phytomass (0.5 t ha^{-1}) and its indicator NDVI (≤0.07) below which the ***negative*** feedback changes over to positive one, has been determined. Anthropogenic degradation of vegetation accelerates attaining of the threshold value of the phytomass and subsequently the expansion of climate-related desertification.

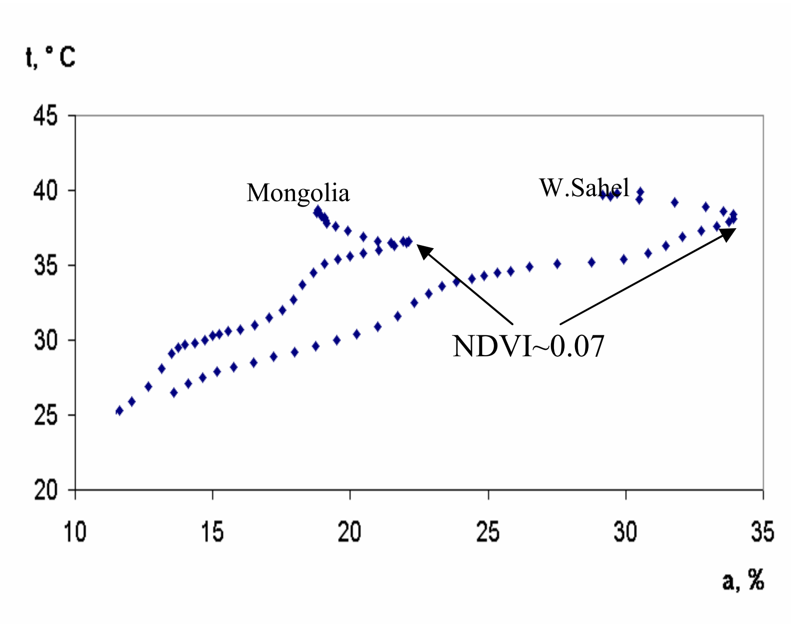
Relationship between monthly surface albedo (as) and temperature (ts) along south-north transect through the Caspian Lowland (47.5-52N, 48-51E). May-September 1985-1991. Data from Gutman et al., 1995.



Observations supporting the hypothesis

Analysis of surface heat balance observations in Northern Eurasia and Northern Africa reveals negative correlation between albedo and surface temperature in arid areas where the radiative mechanism of surface energy exchange is dominating while a positive correlation is typical for subhumid areas where evapotranspiration plays a significant role. Semiarid areas differ from the surrounding territories by increased variability of energy fluxes and a decrease of correlation between albedo and surface temperature. Thus, there is threshold albedo value determined by vegetation of semiarid areas. If the albedo is above the threshold value, the evapotranspiration regulation mechanism of surface temperature is changed to a radiative one, which increases aridity and is a precursor of desertification. This threshold is close to a no-return point when desertification begins.

Relationship between monthly surface albedo (a_s) and temperature (t_s) along a south-north transect through West Sahel (14-20N, 12-15W) and Mongolia (42-49N, 103-108E). May-September 1985-1991. Data from Gutman et al., 1995



- The picture shows switch of the surface energy exchange mechanism in other dry regions (Mongolia and West Sahel). The values of the threshold albedo are different in these dry regions. But the switch of the surface energy exchange mechanism was observed inder equal values of mean seasonal NDVI.

Another support of the hypothesis. Numerical experiments for tropic areas (Polcher,1995).

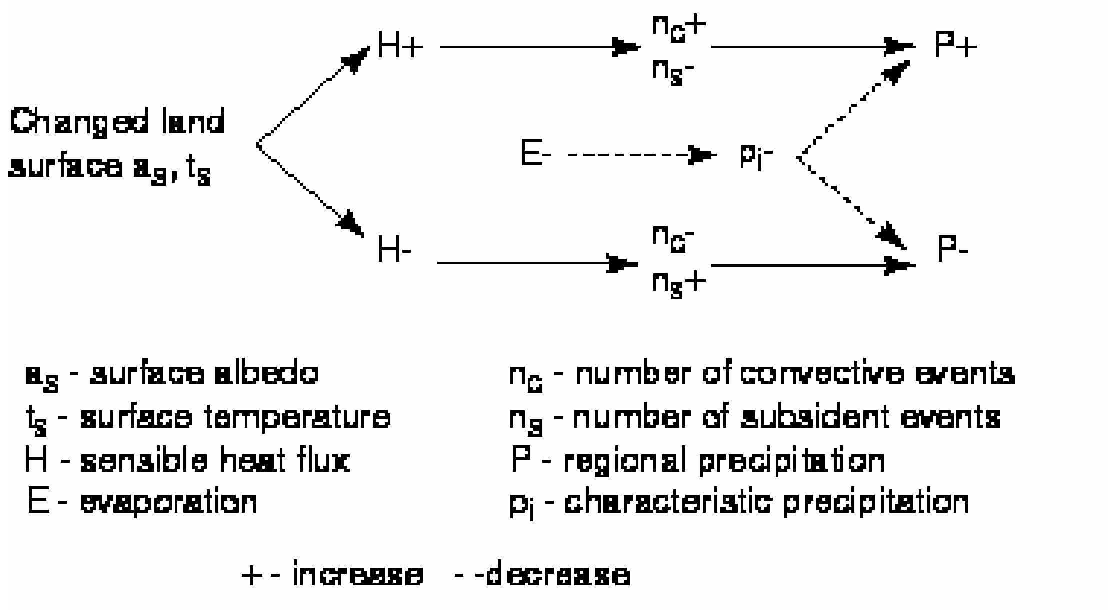


Fig. 3. Schematic representation of the sensitivity of tropical convection to land surface changes in the LMD-GCM (Polcher, 1995).

The different surface albedo (a_s) and temperature (t_s) changes imposed to the LMD-GCM lead to increases as well as reductions of the sensible heat flux (H). If H is reduced (negative correlation between a_s and t_s), the frequency of convection is lowered, which tends to diminish regional precipitation. An increase of subsident events is also found (positive feedback, Charney's mechanism). A higher H leads to the converse effect (negative feedback). ***The critical question is raised: what is the sensitivity of convection to land surface changes in semiarid lands of Northern***

The areas of climate-related component of desertification

- Area dominated by the climate-related desertification is a territory, where, in most cases, green phytomass attains threshold value (≤0.5 t ha^{-1}; NDVI≤0.07) in seasonal and interannual changes. We use NDVI≤0.07 as a parameter for monitoring the climate-related desertification (the aridization indicator). Indicator is determined as the time period when it takes for NDVI≤0.07 during the vegetation season.
- As a rule, the area includes a part of arid and semiarid lands in case of slight anthropogenic degradation of the vegetation cover. Sometimes the area expanses due to dry subhumid lands degraded as a in result of human activities. In the late 20th century importance of the anthropogenic degradation of dry lands as additional regulator of positive feedback increases.

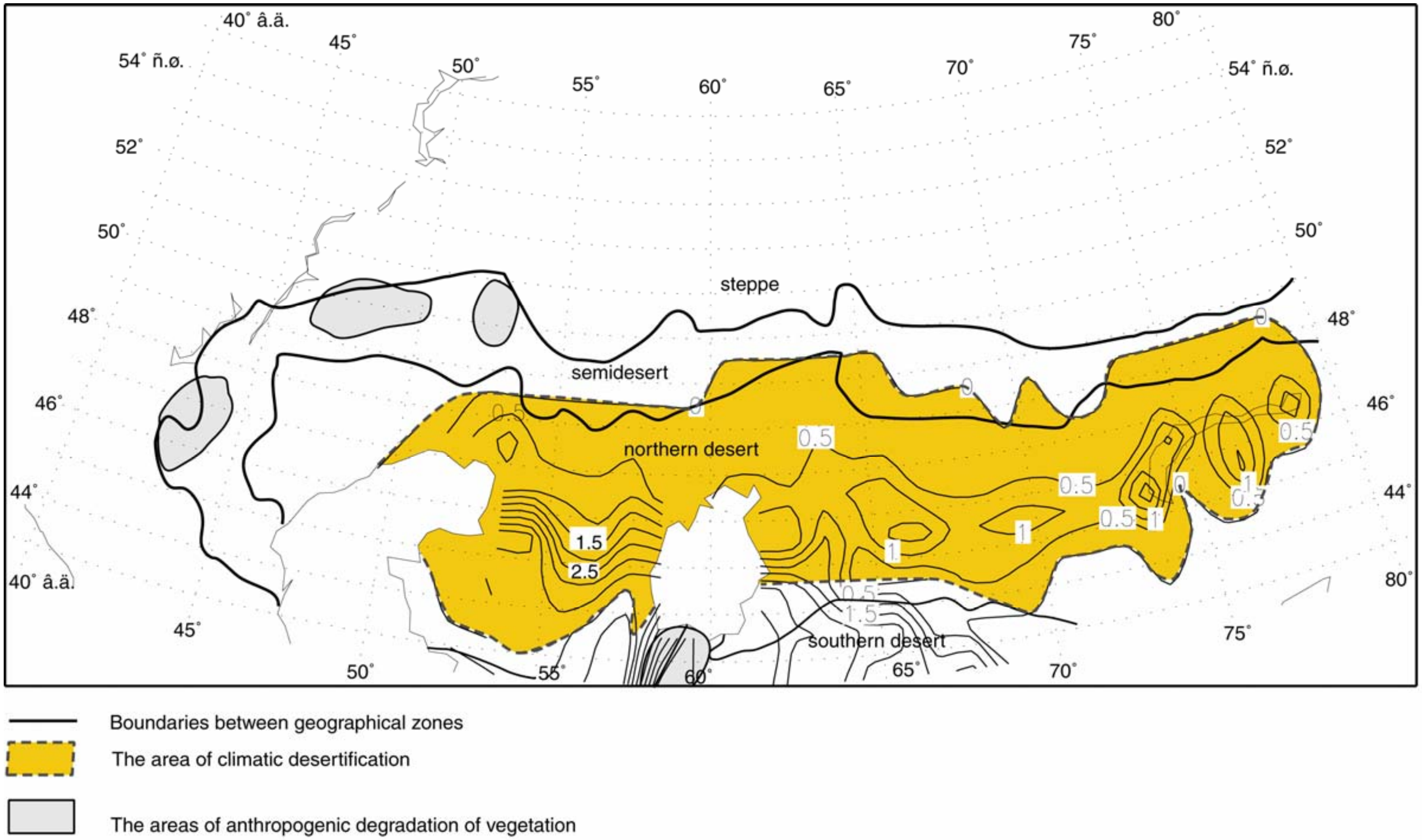


Fig. 6. The North-Turanskiy area of climatic desertification and geographical zones.
Isolines - indicator of climatic desertification in month/M.-S. (NDVI ≤ 0.07). May-September 1982-2001.

The area subjected to the climate-related desertification process in Central Asia occupies the most part of semiarid lands (the zone of northern desert).

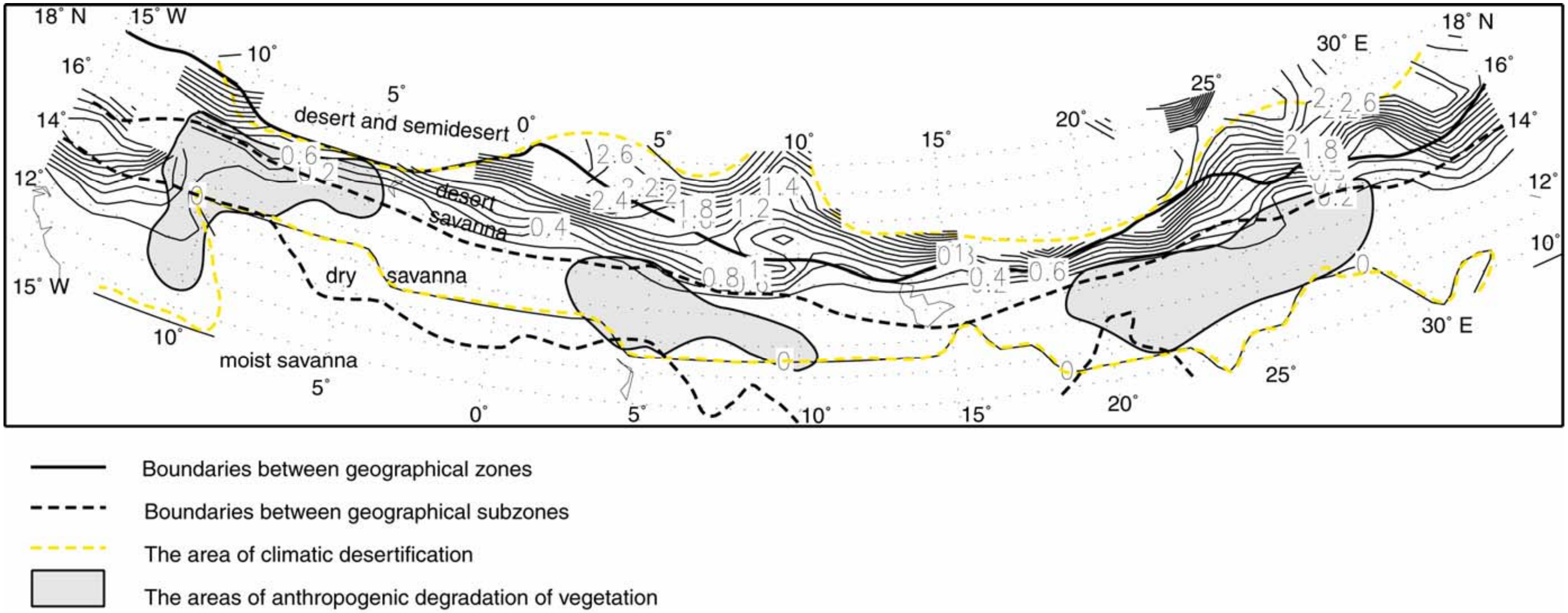


Fig. 7. The Sahel area of climatic desertification and geographical zones.
Isolines - indicator of climatic desertification in month/J.-S. (NDVI ≤ 0.07). July -September 1982-2001.

Sahel area of climate-related desertification has expanded in the Western Sahel in the late 20th century due to inclusion of dry subhumid lands.

Comparison of the past decade (1992-2001) to the previous decade (1982-1991)
The areas of climate-related deserification

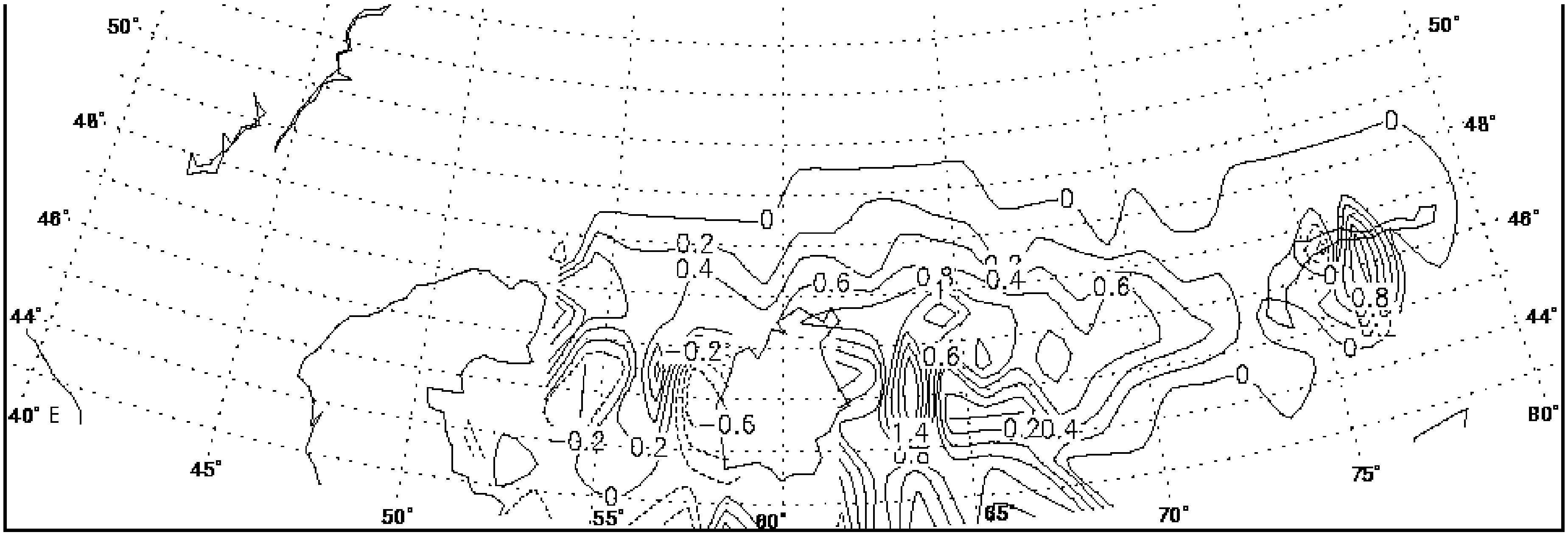


Fig. 10. Change of indicator of climatic desertification in dry lands of the Northern Eurasia for period May-September 1992-2001 in comparison with period 1982-1991.   Isoline in month.

The northern limit of the area subjected to the desertification process in Central Asia has remained stable. The area has expanded southward as a result of drying the Aral Sea and landscapes of the Amu-Darya and Syr-Darya delta plains. Comparison of the past decade (1992-2001) to the previous decade (1982-1991) revealed a tendency of reduction of the desertification in the Caspian Lowland and its intensification in the areas between the Aral Sea and Lake Balkhash.

Comparison of the past decade (1992-2001) to the previous decade (1982-1991)
The areas of climate-related deserification

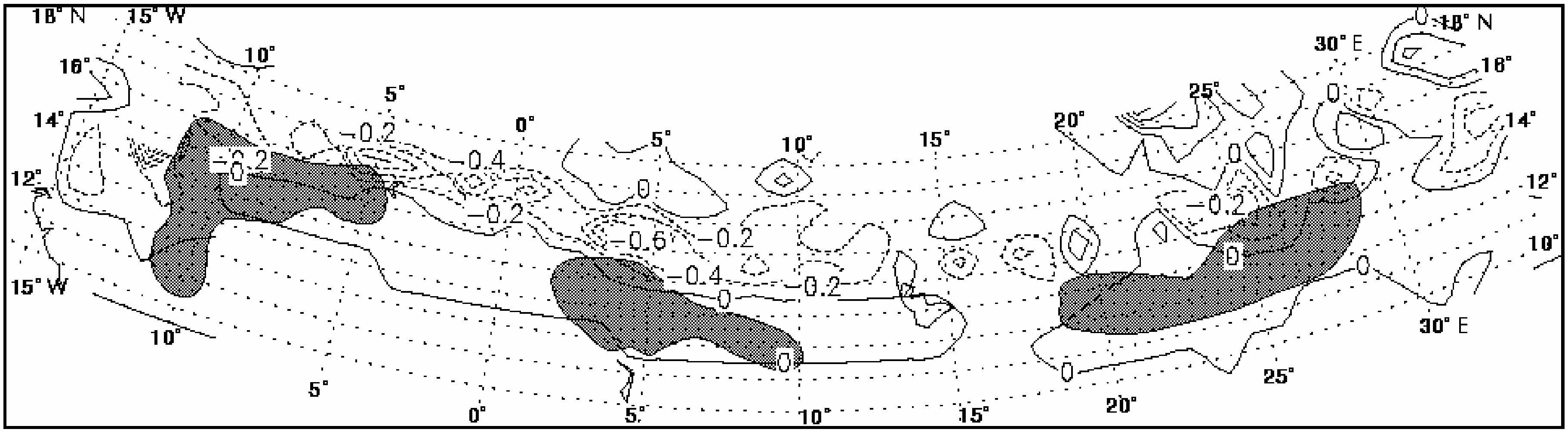
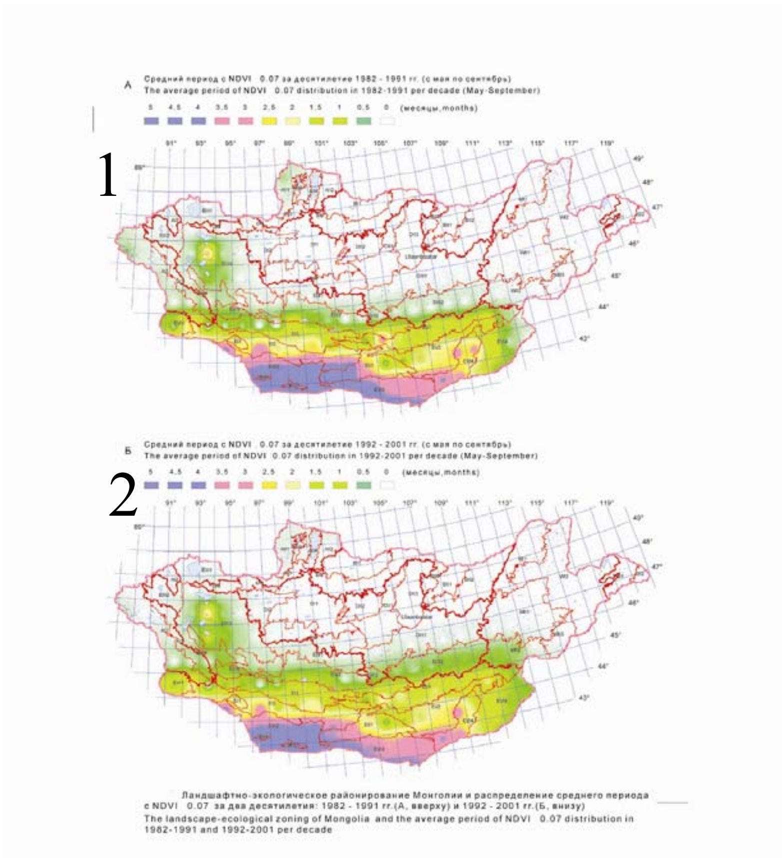


Fig. 11. Change of indicator of climatic desertification in dry lands of the Northern Africa for period July -September 1992-2001 in comparison with period 1982-1991. Isoline in month.

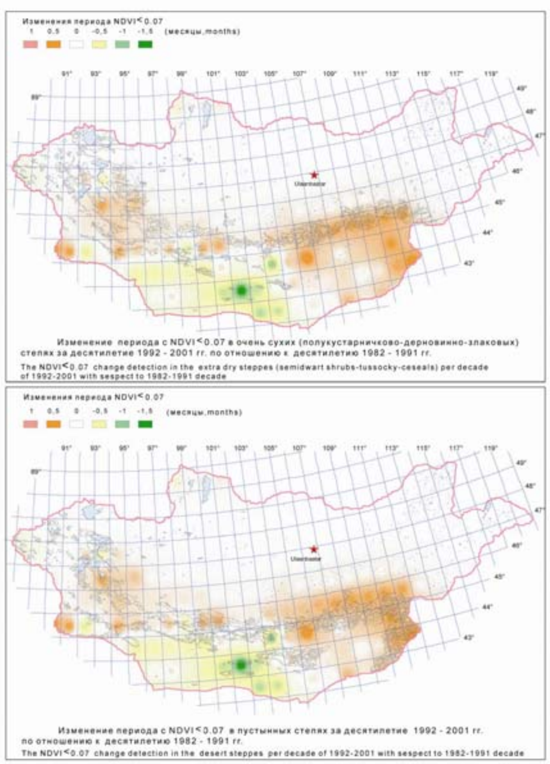
Comparison of the past decade (1992-2001) to the previous decade (1982-1991) revealed a tendency of reduction of the climate-related desertification in Sahel.

Colors indicate the aridization areas in 1982-1991(1) and 1992-2001 (2). The aridization indicator is expressed in months during May-September



- The aridization area is maximal during 1992-2001as compared to 1982-1991. The aridization has spreaded across Lake region and North Gobi.

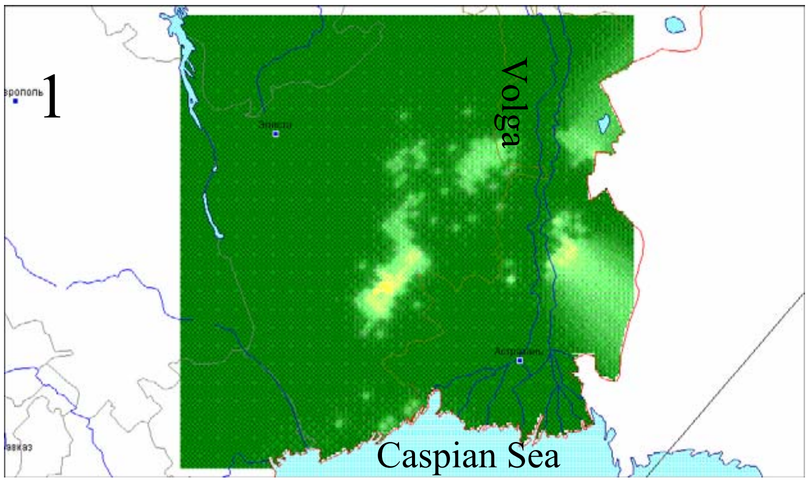
Zonal ecosystems and the difference of aridization indicator (in months) between 1992-2001 and 1982-1991 during May-September. The positive values represent longer aridization in 1992-2001 than in 1982-1991.

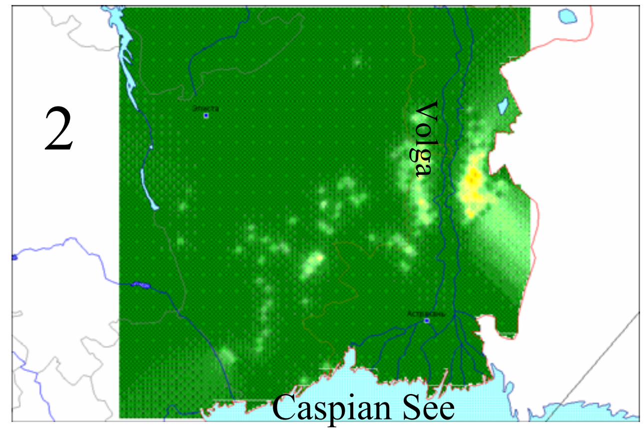


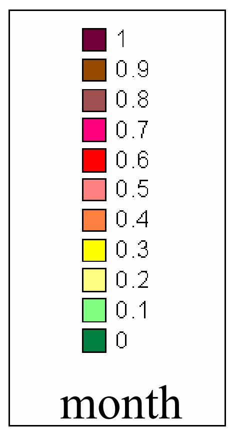
- The aridization indicator has increased in 1992-2001 in ecosystems of dry steppes and has become observable in southern part of the dry steppes, as well as in tussoc-grass steppes of the Eastern Mongolia. However, local decrease of aridization indicator was observed in the Southern part of the country.

Indicator of local anthropogenic aridization (in months) in 1982-1991(1) и 1992-2001 (2) in the south-east of European Russia (Kalmykiya and Astrakhan'oblast') during May-September.

Local changes of different sign take place







CONCLUSIONS

- **A simple indicator of climate-related desertification (aridization), using remote sensing data (NDVI) is proposed. It is based on domination of the radiative mechanism of surface energy exchange in dry lands.**
- **The hypothesis of regional *positive* and *negative feedbacks* related to albedo and precipitation changes is analyzed.**
- **The specifics of aridization changes in different dry lands of Northern Eurasia and Northern Africa in 1982-2001 are revealed.**