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Сборник включает материалы, представленные на Международную конференцию ИнтерКарто/ИнтерГИС 15. Рассматриваются теоретические и методические аспекты геоинформационного обеспечения задач устойчивого развития, в том числе вопросы геополитики и управления территориями, инфраструктуры пространственных данных, роль дистанционного зондирования Земли в обеспечении устойчивого развития, проблемы и перспективы решения водно-экологических, геоморфологических, геологических и геофизических проблем, опыт разработки экологических ГИС-проектов для устойчивого развития, вопросы устойчивого развития и туризма, образования и обучения для устойчивого развития.

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EVALUATION OF SAND RELIEF TRANSFORMATION IN THE NORTH OF THE
TYUMEN REGION BASED ON THE REMOTE SENSING DATA

O.S. Sizov, A.V. Soromotin, A.A. Sizova, O.V. Gerter
Research Institute for Environment and Rational Use of Natural Resources, Tyumen State University,
Tyumen, Russia

Abstract. This work is dedicated to major features of sand terrain transformation in the north of the Tyumen Region, which results from natural as well as anthropogenic factors. There is an evaluation of long-term dynamics in bare sand area in natural conditions and in the areas of active oil and gas extraction activity. The analysis is based on remote probing data of various years, with all the results presented in unified geo-information system.

Introduction
Sand terrain, formed by wind force, is widely-spread not only in arid and semiarid regions, but in northern parts of inland glaciation areas all over the world. For example, partly arrested dunes in central and north Alaska has the area of 30000 sq. km. [Djikmans, Koster, 1990]. There are known sand sediments on the White Sea coast, in the Bolshezemelskaya tundra, on the Yamal, Chukotka peninsulas and in Yakutia. In the north of the Tyumen region eolian terrain is also widely spread, mainly on the terrain of big rivers, such as the Nadym, the Pur, the Ajyasedapur, the Pakupur, the Leo and in high basin dividing areas. Its formation is based on conditions of an abundant supply of sandy sediments accumulation in the period of boreal sea transgression (the upper and middle Pleistocene) and on glacial retreat, accompanied by disastrous floods in moraine – dammed basins. After drying-out, sands of different origin underwent significant exposure to wind. Some researches [Zemtsov, 1976] distinguish up to 5-6 periods of dynamic aeolian activities in the Pleistocene. The existence of aeolian terrain forms and large dunes, poorly fixed by vegetation, determines the development of contemporary aeolian terrain formation processes. Nowadays, among other natural factors considerable wind force and territory’s wind regime features favour the existence of vast denuded sandy areas. However, technogenic activities, connected with oil and gas field development, plays an important role in terrain disturbance and the formation of desertified areas. In the official sources there is only general data on the damaged territories size per annum without singling out deflation prone regions.

Thereby, the aim of this research is to evaluate sand terrain transformation degree in the last decades of development in natural conditions as well as in industrial areas.

In the course of the research, the following objectives were put:
- to explore two representative areas of natural and natural-technogenic terrain formation;
- to classify sand terrain forms in these areas, with singling out the class of natural-anthropogenic terrain;
- to evaluate denuded sands dynamics under the conditions of industrial exploration, basing on non-simultaneous space remote sensing data;
- to evaluate natural aeolian terrain dynamics, basing on non-simultaneous space remote sensing data;
- to perform the comparative analysis of the received data.

Data and area for the study
In this research contemporary methods of satellite image interpretation were used, all the results are presented and analyzed in geo-information system.

Non-simultaneous satellite data include:
- multispectral images from the Landsat-5 satellite with 28,5 m. spatial resolution (data on area’s condition as of 1987-1988);
- images from the Landsat-7 satellite with 28,5 m. multispectral and 14,5 m. panchromatic spatial resolution (data on area’s condition as of 2001);
- images from the SPOT – 2/4 satellites with 10 m. panchromatic spatial resolution (data on area’s condition as of 2006).

Images from the SPOT – 2/4 satellites were kindly provided by the Engineering Centre “ScanEx” (Moscow) as a part of the non-profit organisation “The Transparent World” tender. Images from Landsat-5 and Landsat-7 satellites were taken from the archives of the Research Institute for Environment and Rational Use of Natural
Resources, Tyumen State University. In addition, archival data on field boundaries and contemporary development pressure were used.

Methodologically the research had several successive steps:
- geoprocessing and integration of all mentioned remote data into geo-information system project;
- sand areas digitization using teaching classification based on non-simultaneous remote data;
- the received vector percolation and correction. Correction and removal of the noisy data, received from panchromatic SPOT image (2006) was made according to Landsat image from 2001;
- mapping field boundaries.
- carrying-out geo-information system analysis, including sandy sediments division into natural and anthropogenic, and estimation of sandy areas changes for each zone.

The territory choice was stipulated by two factors:
- all kinds of aeolian terrain forms existence on confined areas;
- the existence of oil and gas fields and man’s impact signs.

Taking into account these conditions there were chosen two areas of natural and anthropogenic aeolian terrain formation development

As a natural terrain development area, the Nadym River middle course was chosen, since there are no oil and gas fields. At the same time large areas are subjected to aeolian erosion. The size of large deflation basins can vary from 2 to 5 km or more in length, and the overall sandy sediments area is more than 160 sq.km. The areas length is 140 km. from south to north and 75 km. from west to east. Sandy sediments can be divided into three regions: the Nadym River terrace complex, the first and second-order tributaries terrace complexes and high basin dividing areas.

As an area under technogenic influence, the Pakupur River left bank lower reaches were chosen, since on a rather limited territory there are 7 large oil and gas fields: Komsomolskoe, Barsukovskoe, Novo-Purpeiskoe, Verkhnje-Yangitinskoe, Muralvenkovskoe, Vingaakhinskoe, Gubkinskoe. The length of this area is 85 km. from south to north and 70 km. from west to east. In evaluation the areas of Muralvenko, Gubkinskoe and Purpe settlements are not taken into account, as sand sediments area is lowered there as a result of constant gardening and landscaping. The emphasis is made on natural deflation development areas and fields’ territory, where restoration works on sand fixation are hardly performed.

**Results and discussion**

The classification of the current types of sand terrain which characterize the area of the investigation is presented in Table 1. It is based on the field research data, on the results of the analysis of the high-resolution satellite images, and on the relevant literature sources.

*Table 1. Aeolian terrain types classification*

<table>
<thead>
<tr>
<th>Aeolian-phytogenic</th>
<th>Positive</th>
<th>Dunes, dune-like hilly formations, hillocks, sites of areal accumulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>Funnels, basins and deflation areas</td>
<td></td>
</tr>
</tbody>
</table>

**Natural-anthropogenic terrain types**

<table>
<thead>
<tr>
<th>Linear</th>
<th>Unpaved highways, pipeline routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areal</td>
<td>Shrub plots, industrial sites, open sand-mining sites</td>
</tr>
</tbody>
</table>

Natural-anthropogenic types of terrain are rather easily decoded and recognized on the high-resolution satellite images. In the image decoding and interpreting process both the area visibly affected and area of the likely deflation were taken into consideration as the latter is a potential source of sand material transfer and thus an indicator of anthropogenic disturbances of terrain.

At the same time, natural deflating hollows are often affected themselves by road construction thorough them, by sand mining activities etc. Such cases were manually selected with higher level of accuracy.

Sets of data presented in Tables 2 and 3 were obtained through the analysis of the territory with natural sand terrain.

*Table 2. Changes in the denuded sand area, middle reach of the Nadym River (1988-2001)*

<table>
<thead>
<tr>
<th>Location</th>
<th>S, hectare 1988</th>
<th>S, hectare 2001</th>
<th>ΔS, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrace complex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- submeridian section of the river bed</td>
<td>12121,09</td>
<td>11270,28</td>
<td>-7,0</td>
</tr>
</tbody>
</table>

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ДИСТАНЦИОННОЕ ЗОНДИРОВАНИЕ ЗЕМЛИ И УСТОЙЧИВОЕ РАЗВИТИЕ ТЕРРИТОРИЙ

| - sublatitudinal section of the river bed | 2501,668 | 2148,98 | -14,1 |
| Basin divide area | 1223,97 | 1169,21 | -4,5 |
| - To the east of the river bed | 408,9 | 349,69 | -14,5 |
| - To the west of the river bed | 2229,58 | 1421,96 | -36,2 |

Table 3. Dynamics of the 15 biggest deflation basins of the Nadym River basin (1988-2001)

<table>
<thead>
<tr>
<th>№</th>
<th>S, hectare 1988</th>
<th>S, hectare 2001</th>
<th>ΔS, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>365638,78</td>
<td>347007,99</td>
<td>-5,10</td>
</tr>
<tr>
<td>2</td>
<td>167107,52</td>
<td>156654,10</td>
<td>-6,26</td>
</tr>
<tr>
<td>3</td>
<td>91694,36</td>
<td>87871,81</td>
<td>-3,18</td>
</tr>
<tr>
<td>4</td>
<td>47143,39</td>
<td>72395,10</td>
<td>-2,36</td>
</tr>
<tr>
<td>5</td>
<td>72000,25</td>
<td>70440,04</td>
<td>-2,17</td>
</tr>
<tr>
<td>6</td>
<td>65148,44</td>
<td>59002,74</td>
<td>-9,43</td>
</tr>
<tr>
<td>7</td>
<td>56241,67</td>
<td>55899,76</td>
<td>-0,61</td>
</tr>
<tr>
<td>8</td>
<td>54731,30</td>
<td>51056,08</td>
<td>-6,72</td>
</tr>
<tr>
<td>9</td>
<td>48498,40</td>
<td>44726,96</td>
<td>-7,78</td>
</tr>
<tr>
<td>10</td>
<td>37626,18</td>
<td>36383,83</td>
<td>-3,30</td>
</tr>
<tr>
<td>11</td>
<td>34787,74</td>
<td>33261,63</td>
<td>-4,39</td>
</tr>
<tr>
<td>12</td>
<td>32718,61</td>
<td>31108,88</td>
<td>-4,92</td>
</tr>
<tr>
<td>13</td>
<td>27842,79</td>
<td>25013,97</td>
<td>-10,16</td>
</tr>
<tr>
<td>14</td>
<td>25829,64</td>
<td>24311,67</td>
<td>-5,88</td>
</tr>
<tr>
<td>15</td>
<td>21955,83</td>
<td>20523,66</td>
<td>-6,52</td>
</tr>
</tbody>
</table>

Decoded data show that each location can be characterized by the moving sand area reduction which accounts 11, 5% for some. Comparison of areas of bigger deflation basins (more then 2 sq.km.) also demonstrates the net negative dynamics of the open sand surfaces. However, the contraction is not dramatic and exceeds 10% only in one case. This indicates relative stability of Aeolian formations within the current boundaries as well as the equilibrium within the terrain system and lack of further development of deflation processes in natural conditions.

Results of the investigation of the area under industrial development are presented below in Tables 4, 5 and 6.

Table 4. Sand denudation dynamics at several minefields (natural Aeolian terrain)

<table>
<thead>
<tr>
<th>Minefield</th>
<th>S, hectare 1987-1988</th>
<th>S, hectare 2001</th>
<th>Accession in comparison to previous date, %</th>
<th>S, hectare 2006</th>
<th>Accession in comparison to previous date, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barsukovskoe</td>
<td>123</td>
<td>119,6</td>
<td>-2,8*</td>
<td>131,2</td>
<td>9,8</td>
</tr>
<tr>
<td>Vingaiakhinskoe</td>
<td>248</td>
<td>411</td>
<td>65,7</td>
<td>1164,2</td>
<td>183,3</td>
</tr>
<tr>
<td>Gubkinskoe</td>
<td>182,7</td>
<td>139,4</td>
<td>-23,7</td>
<td>176</td>
<td>26,2</td>
</tr>
<tr>
<td>Muravlenkovskoe</td>
<td>8,2</td>
<td>56,6</td>
<td>588,8</td>
<td>39,7</td>
<td>-29,8</td>
</tr>
</tbody>
</table>

* Negative dynamics values are marked in red
**Table 5. Sand denudation dynamics at several minefields (anthropogenic Aeolian terrain)**

<table>
<thead>
<tr>
<th>Minefield</th>
<th>S, hectare 1987-1988</th>
<th>S, hectare 2001</th>
<th>Accession in comparison to previous date, %</th>
<th>S, hectare 2006</th>
<th>Accession in comparison to previous date, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barsukovskoe</td>
<td>536,5</td>
<td>1442,8</td>
<td>168,9</td>
<td>1689,8</td>
<td>17,1</td>
</tr>
<tr>
<td>Vingaiakhinskoe</td>
<td>173,1</td>
<td>1060</td>
<td>512,5</td>
<td>1155,9</td>
<td>9,0</td>
</tr>
<tr>
<td>Gubkinskoe</td>
<td>420,2</td>
<td>1001,3</td>
<td>138,3</td>
<td>1939,5</td>
<td>93,7</td>
</tr>
<tr>
<td>Komsomolskoe</td>
<td>435,8</td>
<td>926,4</td>
<td>112,6</td>
<td>998,8</td>
<td>7,8</td>
</tr>
<tr>
<td>Muravlenkovskoe</td>
<td>1021,7</td>
<td>1652,8</td>
<td>61,8</td>
<td>2214,4</td>
<td>34,0</td>
</tr>
<tr>
<td>Novo-Purpeiskoe</td>
<td>634,2</td>
<td>527,7</td>
<td>-16,8*</td>
<td>881,3</td>
<td>67,0</td>
</tr>
<tr>
<td>Verkhne-Yangitinskoe</td>
<td>1,5</td>
<td>61,8</td>
<td>3960,2</td>
<td>137,8</td>
<td>123,2</td>
</tr>
</tbody>
</table>

* Negative dynamics values are marked in red

**Table 6. Share of the denuded sand area in the whole area of the oil and gas fields as of 2006**

<table>
<thead>
<tr>
<th>Minefield</th>
<th>Natural Aeolian terrain</th>
<th>Anthropogenic Aeolian terrain</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Barsukovskoe</td>
<td>1,2</td>
<td>15,7</td>
<td>16,9</td>
</tr>
<tr>
<td>Vingaiakhinskoe</td>
<td>3,5</td>
<td>3,5</td>
<td>7,0</td>
</tr>
<tr>
<td>Gubkinskoe</td>
<td>0,3</td>
<td>3,2</td>
<td>3,5</td>
</tr>
<tr>
<td>Komsomolskoe</td>
<td>0,0</td>
<td>9,5</td>
<td>9,5</td>
</tr>
<tr>
<td>Muravlenkovskoe</td>
<td>0,2</td>
<td>8,4</td>
<td>8,6</td>
</tr>
<tr>
<td>Novo-Purpeiskoe</td>
<td>0,0</td>
<td>10,2</td>
<td>10,2</td>
</tr>
<tr>
<td>Verkhne-Yangitinskoe</td>
<td>0,0</td>
<td>7,0</td>
<td>7,0</td>
</tr>
</tbody>
</table>

On the basis of the data presented above the following conclusions may be drawn:

1. Differently directed natural terrain dynamics originates from difficulties in distinguishing it from the anthropogenic terrain. At those locations where natural deflation basins are getting affected by anthropogenic activities, their area increase is likely to be significantly intensified (e.g. Muravlenkovskoe minefield). Same effect is also observed at Barsukovskoe and Vingaiakhinskoe minefields. In the former case there are ongoing minefield developing activities being carried out, as in the latter case the area being exploited is largely affected by wind erosion and is extremely deflation sensitive.

2. Negative values of the terrain dynamics indicate that deflation basins have not been disturbed, yet as observations show that with prolongation of the minefield works there are almost no undisturbed deflation basins left.

3. With regard to the anthropogenic terrain almost all data samples (except for Novo-Purpeiskoe minefield as of 2001) show steady growth in the area of disturbed territories. During 1988-2001 period deflation was the most significant, decreasing afterwards.

4. The highest values of denuded sand area represent Verkhne-Yangitinskoe (fig. 2) Vingaiakhinskoe (fig. 3) and Barsukovskoe minefields, especially in the period from 1988 to 2001. In case of Verkhne-Yangitinskoe minefield there were no indications of the denuded sand presence prior to the beginning of the minefield development, however, currently the area of denuded sands exceeds 130 hectares as of 2006.

5. It should be noted that maximum values of the denuded sand dynamics is indicative for the periods of minefield primary development and construction stages when the largest impacts on terrain are done. Thus, such minefields as Gubkinskoe and Verkhne-Yangitinskoe are currently under the largest pressure.

6. It has been found that even with reduced rates of minefield development no vegetation restoration occurs. It happens due to continuing distortion of the area because of unregulated traffic, forest fires and logging. Field observations showed that even when recultivation activities were carried out (in cases of sand quarries) there was almost no or very little vegetation restoration - mainly due to availability of close to surface ground water sources.

7. Share of denuded sands on the territory of all minefields comprises from 3.5 to 16.9%. Additionally, there exists a direct relationship between the sand terrain share values and a minefield exploitation timeframe: the longer the timeframe is, the larger is the disturbed area. In most cases the share of the anthropogenic terrain area exceeds
the natural one. An average value of disturbed terrain equals 9% indicating a large scale impacts. Moreover, taking into account all natural factors it is likely that areas of denuded sands will remain within the boundaries of automorphic forests even after the closure of all industrial activities. Vegetation restoration should become a priority for biological recultivation of the minefield areas.

Fig. 2. Denuded sands dynamics of the Verkhne-Yangitinskoe minefield (1-in 1988, Landsat-5 image, Research Institute for Environment archives; 2 – in 2001, Landsat-7 image, Research Institute for Environment archives; 3 – in 2006, SPOT-4 image, kindly provided by the Engineering Centre 'ScanEx')
Conclusion

Results of the research suggest that in natural conditions processes of denuded sands recovery do gradually occur as sand in time accumulates in front of vegetative barriers preventing further deflation. However, industrial exploitation of minefield areas results in large scale distortions of soil mantle. Existing deflation basins are being under constant pressure of transformation – integrity of swells is distorted due to arrangements of industrial sites and sand mining. Moreover, many new sources of further deflation evolve in the situation when the natural vegetation restoration is challenged and very limited. It is very likely that without immediate comprehensive measures for recultivation of affected areas along with introduction of strict regulations for all industrial activities, depleted minefield areas will represent anthropogenic deserts among common northern landscape for long periods of time.

Data obtained from the research shape a uniform geo-information system which comprises vector layers representing denuded sands for each focal year and bitmap layers of satellite images. The research is to be continued in the direction of monitoring and updating databases on sand terrain developments within the boundaries discussed in this paper and in the neighboring territories which would contribute to the work on combating desertification as well as help decision-makers in more sustainable land management.

REFERENCES