Dynamics of steppe arable land in zones of oil fields development (Orenburg region)

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Abstract. The reported paper presents the analysis data on the arable land dynamics in oil extraction zones. The long-term development of oil fields leads inevitably to farmland losses for a variety of destructive processes and, as a consequence, to withdrawal of lands from a turnover, and land abandonment. Our study was carried out on two sample territories in the steppe zone of Orenburg region with two key land utilization sectors – agriculture and long-term oil extraction. To reveal the dynamics of agricultural lands and oil fields we adapted time series of satellite (Landsat) imagery. An analysis was divided into several phases dealing with quantity-related assessment of fields withdrawn from the farmland turnover and tracing the relationship between their position and objects of oil extraction infrastructure. A period of interest covered 40 years – from 1980 to 2020. The research has highlighted a thirteen and eightfold increase of zones with oil production facilities on the first and second territory, respectively. Recently, 24% and 26% of oil fields are located on arable lands. Another outcome of the study is that the expansion of territories designated for subsurface use is the reason that both directly abandoned areas and neighboring lands are removed from the farmland turnover. Agricultural lands affected by oil fields are at a high risk of being withdrawn from the turnover – losses may range to the firth of arable lands.

1 Introduction

Agriculture is a major economy sector in regions of steppe lowlands; therefore, farmlands dominate in the steppe landscape. In the context of threatening food scarcity at the global level a priority is supposed to be a comprehensive assessment of a relationship between agriculture and parallel economic activities, such as oil production. Industrial facilities of oil extraction are incorporated into the existing agricultural environment of steppe regions and create additional powerful sources of man-induced effect and synergy of impact that cause special multifaceted transformations of landscapes, and frequently even a loss of efficient arable lands.

A geo-ecological component in any global large-scale manufacturing activity plays an important role for modification and social and economic situation in all territorial and geographical segments since environment, economy, and society represent coupled systems. Almost fifty oil fields are developed in steppe regions of the Russian Federation with a tremendous man-made effect on natural and agricultural landscapes. Therefore, one of the conflict aspects influencing the co-existence of agriculture and oil
production is related to removal of efficient farmlands from agricultural land turnover in order to develop profitable oil fields. At the same time, oil is the most important natural recourse; undoubtedly, its production is needed and driven by economic forces, as a result, areas within any categories of farmland may be rendered suitable for this economic activity. In many cases long-term development of oil fields brings about farmland losses, e.g. because of chemical or thermal pollution of landscape components (Myachina, Chibilev, 2020), activated erosion of soils (Ermolaev et al., 2012), and other destructive processes, as a consequence, these lands are taken out from the agricultural land turnover and get abandoned. An exclusively output-oriented activity of companies involved in extraction of natural recourses, an aim to maximize profits at the expense of a geo-ecological state of a territory give rise to mentioned above instances.

This research had a purpose to analyze the dynamics of arable land areas located near oil fields being developed on a long-term basis.

2 Objects and Methods
Our study was carried out in the steppe zone of Orenburg region, where agriculture and oil production are key sectors in land utilization. Two sample territories were selected and met two basic requirements: 1 – an existing agricultural activity, 2 – running oil fields close to or within the boundaries of agricultural lands. Sample territory №1 (approximately 400 km²) was chosen in the lowland water-parting, one zone is designated for agricultural production, the other one represents oil fields being developed since the early 1980-s. Sample territory №2 (approximately 800 km²) is also characterized by a lowland landscape, therefore, numerous agriculturally used areas (ploughlands, pastures or hayfields) alternate with objects of oil infrastructure – a system of oil production facilities has been evolving here since the early 1990-s.

Our study focused on the arable land dynamics in areas adjacent to oil fields comprised several phases dealing with quantity-related assessment of fields withdrawn from the farmland turnover and tracing the relationship between their position and objects of oil extraction infrastructure. A period of interest covered 40 years – from 1980 to 2020.

For the purpose of research we used time series of satellite (Landsat) imagery, controversial issues were clarified by means of historical maps of the platform Google Earth. We selected cloud free photos of the territory under consideration, which were taken every year within the timespan of interest from the middle of April to the end of Mai. A mid-April to late Mai time interval was analyzed on purpose because a majority of fields are tilled at that time. As a result of plowing they contrast with the background on panchromatic images, NDVI imagery, and visual data resulting from the expert photointerpretation.

To trace the dynamics in use of arable lands and areas designated for oil fields infrastructure a period of interest was divided into three time intervals: 1980–1987; 1998–2005; and 2013–2020. Thus, each interval is seven years. Such a time span is necessary not to miss out territories which might be not identified as agricultural lands in the period from the middle of April to the end of Mai (for instance, they might be a part of the crop rotation process, but be planted with winter crops or left fallow during autumn or winter). In addition, within this approach it was possible to identify farmlands, which are tilled spontaneously, i.e. a land user plows up some of fields he owns whenever he wants. As a consequence, a field is classified as a farmland if tilled at least two times during a seven year period, and plowing in the last third of the interval was a strong requirement.

3 Results and Discussion
From the data obtained it is apparent that a maximal area of arable lands was in the interval from 1980 to 1987. An arable land on the first sample territory ranged to 36000 ha and to 17000 ha on the second one, respectively. At that time lands were allotted to oil companies and they started the development of oil fields. It is suggested to be an initial phase in the launching infrastructure facilities of oil production, which were located close to or within the boundaries of arable lands (Figure 1, Figure 2). In the period of interest territories occupied by oil production facilities were insignificant, about 360 ha on the first
sample territory and 260 ha on the second one (1% and 1.5% of a total area size, respectively) and were located mainly beyond agriculturally used lands.

Figure 1. The dynamics of land utilization on sample territory №1: 1 – arable lands in 1980-1987, 2 – in 1998-2005, 3 – in 2013-2020; 4 – oil fields in 1980-1987; 5 – in 1998-2005; 6 – in 2013-2020.

Figure 2. The dynamics of land utilization on sample territory №2: 1 – arable lands in 1980-1987, 2 – in 1998-2005, 3 – in 2013-2020; 4 – oil fields in 1980-1987, 5 – in 1998-2005, 6 – in 2013-2020.
Another time interval under consideration is from 1998 to 2005 and covers a post-crisis time in agricultural production with its less demanded lands (Levykin et al., 2012). We estimate an area of arable lands decreased by 23% on average in the zones under study; whereas territories with oil production infrastructure increased more than eightfold on the first sample territory and fourfold on the second sample territory (see Figure 1 and Figure 2). Importantly, a major part of oil extraction objects was located on arable lands. The objects of oil fields are both on arable and lay lands. For instance, shares of oil wells in the classes: arable lands / lay lands / other territories are 27%/ 42%/ 30% on sample territory №1.

On sample territory №2 a little over 5% zone with oil production objects overlapped with agricultural fields and approximately 7% of them – with lay lands.

Figure 3 and Figure 4 present the dynamics of a ratio between a total area of lay lands on sample territories and an area of lay lands with oil production facilities.

**Figure 3.** The dynamics of a lay lands area on sample territory №1 and oil production infrastructure from 1980 to 2020: 1 – total area of lay lands, 2 – area of lay lands with oil production facilities, 3 – total area of lands with oil production facilities.

**Figure 4.** The dynamics of a lay lands area on sample territory №2 and oil production infrastructure from 1980 to 2020: 1 – total area of lay lands, 2 – area of lay lands with oil production facilities, 3 – total area of lands with oil production facilities.

The third time interval, from 2013 to 2020 is marked with the maximal expansion of lands removed from the agricultural turnover, as well as lands allotted to oil fields (see Figures 1, 2, 3, 4). The graphical data in Figure 3 and Figure 4 demonstrate a growth correlation between areas of oil fields and lay lands.
An area of arable lands in territories under consideration decreased by 40% on average by contrast to that in the 1980-s (the first time interval of interest), whereas an area of territories with oil production facilities increased thirteen and eightfold on the first and second sample territory, respectively. In the total area of territories with oil production infrastructure 24% and 26% of them are located on arable lands on the first and second sample territory, respectively, and 72% and 38% - on lay lands.

The study has revealed that the expansion of territories designated for subsurface use is the reason that both directly abandoned areas and neighboring lands are removed from the farmland turnover. Undoubtedly, the abandonment of farmlands may be a result of different factors (Meyfroidt et al., 2016), but sometimes an aggressive man-induced influence spreading far beyond areas where oil production facilities are located turn agricultural fields adjacent to oil fields into “useless areas” (Myachina, Chibilev, 2020). A land user should take these consequences into account when making a decision whether to withdraw an agriculturally used field from the farmland turnover or continue its targeted use.

It is an obvious fact that a spontaneous and often unreasonable removal of valuable agriculturally used lands from the farmland turnover never ceases unless companies engaged in use of subsurface resources change their attitude to a geo-ecological component of their activity. Such outcomes of oil production industry are in conflict with existing ideas to restrict legislatively the allotment of most efficient agricultural lands to nonfarm uses. The establishment of such untouchable “high-class land fund” can’t be limited to soil rating only; it needs data of high-quality economic, landscape and land-improvement assessment (Chibilev, 2016). This point of view gains more importance in the context of threatening global food deficit and the necessity to meet present day social and environmental challenges.

An analysis of oil well pattern on arable and lay lands on sample territories suggests there should be a critical ratio between an arable land area and an area with oil production facilities, which plays a decisive role for ceasing the agricultural use of a particular field. In our opinion, the determination of this critical value is an essential step in the geo-environmental optimization of landscapes in oil-bearing steppe regions.

4 Conclusion
The proposed procedure of geo-informative analysis concerned with consequences of co-existing agricultural and oil production activities and based on a stepwise assessment of arable lands area takes into consideration the specifics of the farmland turnover on the territory of interest and is supportive when achieving the research aim.

The most important outcome to emerge from the analysis is maps showing the multiannual dynamics of land utilization on territories under study and comprising the tendencies of arable land areas and oil fields.

On territories affected by oil production arable lands are abandoned proportionally to a growing man-induced impact. Therefore, the development of methods to keep valuable agricultural fields bordering with oil fields in the farmland turnover represents a strong requirement for the support of agriculture and social and economic flourishing in oil-bearing regions.

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References
[1]Myachina K V., Chibilev A A 2020 Doklady Earth Sciences 492(1) 366–9.
[2]Ermolaev O P, Rysin I I and Golosov V N 2016 Geomorphology 2 38-51 (in Russian)
[3]Levykin S V, Chibilyov A A and Kazachkov G V 2012 Eurasian Steppes. Ecological Problems and Livelihoods in a Changing World (Dordrecht: Springer) pp 491-505
[4]Meyfroidt P, Schierhorn F, Prischepov A V, Müller D and Kuenmmerle T 2016 Global
Environmental Change 37 1–15.
[5] Chibilev A A 1992 Ecological optimization of steppe landscapes (Sverdlovsk: Institute of plant and animal ecology) p 170 (in Russian)