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Development and transformation of floodplain territories by ants

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Abstract

The article provides an overview of the works devoted to the role of ants in the transformation of floodplain territories and the formation of a peculiar landscape. The importance of floodplain ecosystems characterized by high productivity has been repeatedly noted by numerous researchers. There is ample evidence of the significant contribution of ants to the development and transformation of natural and anthropogenic disturbed areas. However, the contribution of ants and the inhabitants associated with anthills to the formation and development of floodplain ecosystems in Siberia remains poorly understood. The study of the role of ants in the floodplain ecosystems of the Ob will allow us to assess their contribution to changes in the productivity of floodplain soils and predict options for agricultural development of floodplain ecosystems of Western Siberia.

Keywords

Agriculture, ants, ecosystem transformation, floodplain, meadow, soil

Introduction

Floodplain landforms are a surface that is periodically flooded with water. In most rivers, floodplain flooding occurs when the water flow exceeds the channel capacity and flows over the shore. There are floodplains in almost all river valleys. Depend-

ing on the geographical location, floodplains can be flooded several times a year or much less often – once a decade. Floodplains of rivers are important natural objects for agriculture, especially in arid and semi-arid regions where crops are grown on floodplain soils. The fertile soil and the periodic influx of nutrients into the territory, as well as the proximity to a water source, make the floodplain a convenient potential object for agricultural activity (Meitzen 2018).

Floodplain agricultural lands are one of the most productive agricultural ecosystems due to fertile alluvial soils (Chimweta et al. 2018; Yu et al. 2022; Salamanca-Carreno et al. 2023). Seasonal floods lead to the subsidence of fertile sediments in low-lying areas, and sufficient sources of irrigation water contribute to the growth of crops, allowing many crop residues to penetrate into the soil (Qin et al. 2016; Beyene et al. 2019; Yu et al. 2023).

Floodplain meadows make it possible to obtain a sustainable hay harvest; serve as an important source of nectar for pollinating insects; support rare plant communities and are a vital source of seeds for the restoration of meadows. In addition, they provide flood storage sites, capture alluvial deposits and store carbon, and as the climate changes, their value in implementing these functions will only increase; they also provide a historical link with the past, a living reminder of the traditional agricultural landscapes and the lifestyle of the people who settled along the rivers that formed them (Rothero et al. 2016)

In Western Siberia, on the Ob River, floodplain territories occupy vast spaces, and deposits of fertile soil remain practically untouched to this day. Among the so-called Great Rivers of Siberia, it is the Ob River that has the most pronounced floodplain; it is not surprising that it is called the second Amazon. Thus, in the Tomsk forested and swampy region, rivers have always served as the main transport routes. Human settlement and the development of the region's natural resources took place along the rivers. Until now, most industrial centers and settlements in the Ob basin are concentrated near rivers. The Ob River, flowing from the southeast to the northwest of the region for over 700 km, forms a floodplain, the width of which in the south of the region is 6–8 km, and in the north reaches 45 km (Khromykh 1975). Being a place of accumulation of runoff from the entire vast territory of Western Siberia and sensitively responding to processes occurring throughout the entire catchment area, floodplain lands perform an important biosphere function. For the same reason, they are always characterized by more favorable conditions of moisture, heat supply and mineral nutrition compared to non-floodplain areas and therefore represent a rich source of natural resources that have long been developed by humans (Shepeleva 1998).

The purpose of this review is to show the role of ants in the development and transformation of natural and anthropogenic disturbed areas, mostly associated with floodplains of rivers.

Results

The role of ants in ecosystem transformation

The floodplain areas of the Ob River are quite intensively populated by various living organisms, the number and species composition of which changes significantly during the development of floodplain plant communities. In particular, in the Tomsk region, the floodplains are colonized on a large scale by ants, the number of nests of which is increasing in abandoned hayfields and dry meadows (Fig. 1).

Figure 1. Numerous hummocks-anthills of earth ants on a floodplain meadow that came out of haymaking (photo: S.N. Kirpotin).

Thus, in the floodplain of the middle course of the Ob River on floodplain lands withdrawn from agricultural use (cessation of plowing, haymaking), the activity of ground ants and related organisms that produce grandiose work sharply increases. The environment-forming activity of ants is practically not taken into account when studying the modes of functioning and assessing the sequestration potential of floodplain lands, and therefore deserves special attention. The fact is that the ants that have settled on abandoned arable land and hayfields dramatically change all modes of functioning of meadow floodplain ecosystems. First of all, the micro-relief of meadows is changing. It becomes bumpy due to the numerous anthills towering 15–30 cm. There is a sufficiently deep mixing of the upper fertile soil layer. Its aeration is noticeably enhanced.

According to preliminary estimates, the area of non-mowed meadows occupied by anthills in the floodplain of the middle course of the Ob River is at least 60-70%. In addition, due to the continued reduction in the use of floodplain lands for hayfields, the environmental role of ants is dramatically increasing, and therefore requires a comprehensive study and evaluation.

According to the latest research (Simon 2022), according to the most conservative estimates, about 20 quadrillion ants live on our planet, and they weigh more than wild birds and mammals combined. The total mass of ants also corresponds to about one fifth of the total mass of the human population. According to the authors of the study, ants deposit about 12 million tons of dry carbon. Ants, in particular, are an essential part of natural and agricultural ecosystems. Among other things, ants aerate the soil, disperse seeds, destroy organic material, create a habitat for other animals and form an important part of the food chain. Ant dwellings are inhabited by many cohabitants (myrmecophiles), and the flows of "living matter" and dead organic matter through ant settlements allow us to consider the latter as a special kind of consortia.

The role of ants as leading components of consortia and engineering organisms that actively transform the environment is studied in different regions of the world and in ecosystems of different types, including grass: meadows, steppes and prairies (Majer 1983; Beattie 1989; Albrecht, Gotelli 2001; Wodika et al. 2014; Tiede et al. 2017; Wills et al. 2018).

Among terrestrial invertebrates, ants are one of the dominant groups of many ecosystems of the Earth – from the tropics to the tundra (Wilson, Hölldobler 2005). An important ecological role of ants is in interaction with other organisms, which contributes to their global participation in functional ecosystem processes (Hölldobler, Wilson 1990). For example, ants actively regulate the number of populations of numerous groups of arthropods (Edwards 2016). As ecosystem engineers, ants participate in the transformation of the soil by changing its chemical, physical and biological parameters (Frouz, Jilková 2008). Nest building and nutrient extraction are some of the ways ants affect the environment inside and outside of ant mounds. The activity of ants has both long-term and short-term effects on the soil part of the ecosystem through structural changes, accumulation and release of nutrients with possible improvement of soil quality. Studies show that the activity of ants increases the concentration of nitrogen and phosphorus in the soil and reduces the acidity of the soil. Also, ants make the soil more porous (Nkem et al. 2000).

Many ant species play an important role in the transformation of biomass. Decomposition of biomass is an important step in the nutrient cycle, in which complex organic substances are converted into simpler compounds that are necessary to improve soil quality. The presence of large ant species accelerates the decomposition of biomass. Ants in this process act as predators that prey on the larvae of other necrophages, and directly by necrophages. Smaller ant species are also capable of decomposing biomass, but they affect the decomposition process to a lesser extent (Nooten et al. 2022).

Ants, as social insects, have a great influence on soils and soil cover due to the high density of anthills and the fact that during their construction, ants carry a large volume of soil. It has been established that as a result of their vital activity, a number of physical and physico-chemical soil properties change, such as soil composition density, pH, carbon content, temperature regime, as well as microbiological activity (Daineko et al. 2012). Ants in the process of nesting process 26 m^3 per 1 ha. According to some estimates, the total volume of ant nests of *L. niger* L. and *L. flavus* F. species can reach 270 m^3/ha (Zrjanin 2003).

Ants are able to populate regularly flooded areas of land. It is noted that major floods, which differ in their scale from seasonal fluctuations in the water level, do not have a catastrophic effect for all species of ants. Colonies of ground-nesting ants migrate to the trunks of river trees, and therefore, colonies are able to survive in the most flood-prone areas. Some ant species are most resistant to flooding, such as *Iridomyrmex mattiroloi* and *Rhytidoponera metallica*. In regularly flooded areas, ants are able to lead an aboveground lifestyle, erecting nests in trees. It is noted that in the most flooded areas, aboveground ants outnumber terrestrial ants. Adapted species to live in environments regularly prone to flooding have plastic reproductive habits that can provide a competitive advantage, allowing these species to quickly replenish the lost biomass of the colony after a flood. Receding flood waters provide ants with an excess of food, favorably affecting the restoration of the colony. Despite the poor species fauna, ants persist in the floodplain in large numbers. So, on the territory of Australia, in the Barma forest, the number of ants was an order of magnitude greater than beetles and spiders. The abundance of ants suggests that they probably play an important role in the ecosystem processes of the floodplain, especially in relation to the transfer of energy and nutrients between aquatic and terrestrial ecosystems (Ballinger et al. 2007; Khazan et al. 2020).

During the development of the territory by ants, the appearance of the first nests indicates the beginning of intensive modification of the soil cover, which, as a rule, can go in two directions (Nkem et al. 2000; Frouz, Jilkov, 2008). First of all, it is the transport of organic material from the surroundings to the nests as food or building material; secondly, it is bioturbation – mixing and accumulation of soil material from different sources and horizons. Bioturbation has a positive effect on plant growth, which positively affects the recovery rate of disturbed areas (Dostál et al, 2005).

Such large ant species as *F. pratensis* and *F. fusca* can be called ecosystem engineers. They accumulate and mix a large amount of inorganic soil material with organic, thereby enriching the soil with mineral nutrition, changing the pH of the medium and promoting seed dispersal (Gorb, Gorb 1999; Froz, Jilková 2008). Therefore, the dominance of these species occurs precisely on old dumps formed more than 30 years ago, as well as in natural habitats untouched by human activity.

Taking into account the biotopic confinement of ants, as well as their reactions to the levels of anthropogenic impact, four types of ants' reactions were identified in

relation to anthropogenic impacts and the rate of settlement of new sites (Blinova et al. 2021):

1. Adaptive – types of ants that withstand high anthropogenic load. In particular, they are the first to settle on the formed dumps of coal enterprises, with low or complete absence of projective coverage. Often, in the absence of competition, it is these species that are massive in the most polluted or newly formed areas. Over time, the number of such species, as a rule, decreases.

2. Quasi-adaptive – this type of reactions can include species whose abundance is maximum in the "average" period of succession, and at the initial stages it is low. For about 25–30 years of the existence of the dump, the number of nests of these species becomes significant. Further, the density of settlements of these species gradually decreases, reaching minimum values in the control zone.

This type of reaction is characteristic of a number of species of the genus *Formica* (*F. fusca*, F. *cunicularia*, *F. rufibarbis*), as well as the genus *Myrmica* (*M. scabrinodis*, *M. schencki*). Probably, the species assigned to this group do not stand up to competition with the representatives of *Formica* s. str. appearing in the future and during subsequent restoration processes, first reduce the number, then completely disappear.

3. Maladaptive – a type of reaction in which the number of certain ant species decreases with an increase in the degree of contamination or deformation of the ecosystems. On the dumps formed by waste from the coal industry and have passed the technical and biological stages of reclamation, they are among the last to settle. Thus, there is evidence that in the ongoing succession on mine dumps, the nests of *F. aquilonia*, *F. lugubris* appear only with the formation of a tree tier no earlier than 25-30 years after the formation of the dump.

4. The absence of a pronounced reaction is a rare type of reaction of ants, which implies practically unchanged indicators of nest density regardless of the degree of anthropogenic impact. As a rule, representatives of these species lead an underground lifestyle (for example, *L. flavus*, *C. saxatilis*) (Blinova et al. 2021).

It is noted, that for most ants, during the restorative succession in disturbed territories and an increase in the area of vegetation, there is an increase in the density of nests. In addition, there is a change of species: *Lasius niger* appears from the first year of the existence of dumps, and with an increase in the closeness of tree crowns, the density of settlements of this species decreases. This is due to the appearance of forest species of the genera *Myrmica* and *Formica*, which create competition for *Lasius*. (Kabrna 2011; Luzyanin, Blinova 2022). Previous studies (Blinova et al. 2021; Luzyanin, Blinova 2022) have shown that *F. fusca* colonize the dumps 2–3 years after its formation. First, the meadow-steppe *F. rufibarbis* settles, then, at least 10 years later, the eurytopic *F. fusca* and the forest *F. cunicularia* appear.

Studies confirm the positive effect of the settlement of ants on the physical and chemical characteristics of the soils of areas exposed to fire at all stages of the restoration process of disturbed territories. The study was conducted in the Xishuangbanna tropical zone in southwest China. In the course of the work, it was noted

that ants are able to create and maintain high heterogeneity of nutrients in the soil, stimulate the growth of microorganisms and provide space for the development of plants in populated areas at different stages of the restoration of scorched lands (Lu et al. 2019).

The study of fallow soils in the Leningrad and Yaroslavl regions (northern part of European Russia) showed that ant nests complicate the structure of the soil cover: zoogenically processed micro-relief (nests) with a height of up to 0.3 m and a diameter of up to 0.9 m (the ultimate structural element) appears within the elementary soil area. The density of nests can be up to 25 pcs /ha (in the Leningrad region). The volume of soil mass transferred by ants is estimated at 23.3 m^3/ha (Daineko, Rusakov 2012).

Conclusions

Analysis of the published research results shows that ants have a significant and multifactorial influence on the dynamics of floodplain communities. However, to date, there is insufficient information about the impact of ants and their numerous companions (myrmecophiles) on the formation and development of floodplain ecosystems in Siberia. The study of the role of ants in floodplain ecosystems of the middle course of the Ob River will allow us to assess their contribution to changes in the productivity of floodplain soils and predict options for agricultural development of floodplain ecosystems in Western Siberia.

In the next 3 years it is expected:

1. Identify the areas of floodplain lands occupied by anthills;
2. To study the species diversity and distribution of ants and related species associated with ant nests, as well as to assess the density of anthills in ecosystems of different types;
3. Compare carbon emissions and sequestration on anthill-occupied deposits and anthill-free hayfields and arable lands;
4. To give recommendations on the organization of the system of land use of floodplain lands in terms of increasing their sequestration potential.

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