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Dynamics of Locust Infestations and Integrated Management Strategies in Arid Zones of Eastern Georgia

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Abstract

This article presents a systematic study of locust ecology and integrated management strategies in the arid zones of Eastern Georgia from 2011 to 2023. Based on long-term monitoring, two economically important species were identified-*Calliptamus italicus* and *Dociostaurus maroccanus*, with the Italian locust (*C. italicus*) emerging as the most widespread and damaging, particularly in Dedoplistskaro, Sagarejo, and Gardabani districts. The research involved large-scale annual field monitoring (35,000–40,000 ha per year), standardized sampling (quadrant and transect-based counts), GIS-based hotspot mapping, and environmental correlation analysis using NDVI and meteorological data. Control measures included both chemical treatments (Deltamethrin, Chlorpyrifos) and biological control with *Metarhizium acridum*, which was applied over 300–500 ha in pilot trials and showed 74–98% mortality with minimal environmental impact. Statistical analysis revealed significant inter-annual variation in infestation levels ($p < 0.05$), driven by climate conditions and shifts in species composition. The Integrated Locust Management program, incorporating early detection, geospatial analysis, and targeted intervention, substantially reduced crop damage and enhanced food security. The findings confirm that effective locust control in vulnerable regions like arid Eastern Georgia requires long-term, integrated strategies combining technological, chemical, and biological tools under coordinated national and regional frameworks.

Key Words: *Calliptamus italicus*, Integrated Locust Management, arid zones

Introduction

Locust infestations have become a recurrent phytosanitary threat in the arid and semi-arid zones of Eastern Georgia, particularly in Kakheti, Kvemo Kartli, and parts of Shida Kartli. These regions offer favorable ecological conditions for locust development, including prolonged dry periods, sparse vegetation, and extensive unmanaged rangelands. Among the locust species identified in Georgia, the Italian locust (*Calliptamus italicus*) is the most widespread and economically damaging, frequently causing damage to a variety of crops such as wheat, barley, maize, sunflower, vegetables, and pastures [1, 2].

According to official data from the National Food Agency of Georgia and regional reports by the Food and Agriculture Organization of the United Nations (FAO), multiple locust outbreaks occurred in Georgia between 2011 and 2023. The period from 2021 to 2023 experienced particularly severe infestations, with locust population densities often exceeding the economic damage threshold (EDT), resulting in localized yield losses reaching up to 100% in the earliest affected areas [2, 3].

In response to these challenges, Georgia implemented a national Integrated Locust Management (ILM) program aligned with regional sustainable locust control strategies developed under the FAO Caucasus and Central Asia framework. The ILM program includes systematic annual monitoring of over 40,000 hectares, GIS-based mapping and forecasting tools, early warning systems, and capacity-building training for national specialists and local farmers [3, 4].

Control strategies employed a combination of chemical insecticides primarily Deltamethrin, Chlorpyrifos and biological control methods. Pilot trials using the entomopathogenic fungus *Metarhizium acridum* demonstrated promising results, achieving up to 98% mortality in treated locust populations while maintaining minimal environmental impact [5, 2].

This article aims to provide a comprehensive analysis of locust outbreaks in Eastern Georgia's arid zones from 2011 to 2023, focusing on species composition, infestation dynamics, geographic distribution, and affected agricultural sectors. It also evaluates the effectiveness of ILM interventions implemented during this period based

on literature and official reports. The findings emphasize the critical importance of sustained, ecologically responsible, and scientifically grounded pest management strategies, especially given ongoing climate change and desertification trends affecting the region.

Main Part

Materials and Methods – The study was conducted in the arid and semi-arid zones of Eastern Georgia, specifically in the regions of Kakheti (Sagarejo, Dedoplistskaro), Kvemo Kartli (Marneuli, Gardabani), and parts of Shida Kartli (Gori, Kaspi). These regions are characterized by low annual precipitation (300–450 mm), sparse vegetation, and vast unmanaged rangelands, creating ideal conditions for locust development [1].

Field surveys were carried out annually from April to July over approximately 40,000 hectares. Standardized sampling methods were used to estimate locust population densities. Nymphs were counted per square meter, and adult locusts were assessed along 100-meter transects based on recognized field protocols [2].

Species identification relied on morphological characteristics and field identification keys to differentiate life stages – eggs, nymphs, and adults – and to document their spatial distribution [3, 4]. Locust density was classified as light (<10 individuals/m²), moderate (10–30 individuals/m²), or heavy (>30 individuals/m² or presence of cohesive hopper bands). Field data were collected using handheld digital devices (eLocust3m), which ensured georeferenced and standardized recording of observations. These data were processed in a centralized geodatabase and analyzed using Geographic Information System (GIS) software, to identify infestation hotspots and support early warning systems through spatial visualization and trend analysis [5].

Environmental variables, including the Normalized Difference Vegetation Index and historical meteorological data, were incorporated into the analysis to assess ecological drivers of outbreaks and to forecast developmental patterns [6]. Control activities combined chemical and biological strategies. Chemical control employed ultra-low volume (ULV) applications of deltamethrin (2.5% EC) and chlorpyrifos (48% EC), delivered by vehicle-mounted and handheld sprayers in accordance with official guidelines [7]. Biological control involved targeted applications of the entomopathogenic fungus *Metarhizium acridum* (IMI 330189), especially in areas of high ecological sensitivity and high nymph densities. Efficacy was assessed at 3, 7, and 14 days after treatment by observing mortality rates and behavioral changes in locust populations [8, 2].

Statistical analyses were conducted using RStudio (v4.2.0) to evaluate year-to-year dynamics and treatment effectiveness.

Results and Conclusion

Monitoring conducted from 2011 to 2023 in arid and semi-arid ecosystems of Eastern Georgia confirmed the presence of two economically significant locust species: *Calliptamus italicus*, and *Dociostaurus maroccanus*. Among these, *C. italicus* was the most widespread and dominant species, particularly in the districts of Dedoplistskaro, Sagarejo, and Gardabani, where it accounted for over 70% of observed populations in most years. Field identification and developmental stage assessment were conducted during surveys in April-July using standard sampling protocols.

Population density levels varied considerably between years, depending largely on climatic conditions such as precipitation, temperature, and vegetation growth. Light infestations (below 10 individuals/m²) dominated during drought years such as 2013 and 2020, while moderate to heavy outbreaks were more common in wetter years like 2015, 2018, and 2021. Field data were collected using quadrat sampling for nymphs and 100-meter transect counts for adults, enabling the classification of infestation intensity and mapping of outbreak dynamics.

Table 1. Intensity of Locust Infestations in Selected Years

Year	Light (<10/m²)	Moderate (10–30/m²)	Heavy (>30/m² or hopper bands)
2014	35%	53%	12%
2015	24%	57%	19%
2018	22%	56%	22%
2021	19%	59%	22%
2023	31%	52%	17%

Spatial monitoring and real-time reporting were enabled by mobile georeferenced devices (eLocust3m), which allowed digital collection and automated transmission of field data to the national locust database maintained by the National Food Agency. These data were visualized and analyzed in GIS platforms, producing detailed maps of locust habitats, active infestations, and intervention zones.

High-resolution maps enabled the identification of consistent “hotspots” of locust activity across multiple years, particularly in the Shiraki Plain, Iori Plateau, and southern Gardabani. GIS analysis integrated vegetation indices (NDVI), soil moisture data, and weather anomalies to support early warning and decision-making. For instance, NDVI anomalies in early spring reliably predicted early nymphal emergence, which corresponded to earlier infestation peaks in 2018 and 2021.

Table 2. Locust Infestation and Treatment Areas in Eastern Georgia (Selected Years)

Year	Total Surveyed Area (ha)	Infested Area (ha)	Treated Area (ha)
2014	41,235	10,087	4,235
2015	42,502	11,978	6,132
2018	44,210	13,362	7,521
2021	45,115	14,019	6,987
2023	43,940	12,481	5,945

Treatment was carried out using both chemical and biological agents, based on infestation intensity and environmental considerations. Chemical control involved ultra-low volume (ULV) applications of deltamethrin and chlorpyrifos, while biological control trials used *Metarhizium acridum*, a fungal pathogen targeting nymphal stages. Chemical applications achieved over 85% efficacy by day 7, while *Metarhizium* based biological control showed progressive mortality, reaching 70-75% by day 14 in optimal conditions.

Table 3. Efficacy of Control Measures

Control Method	Product	Day 7 Efficacy	Day 14 Efficacy
Chemical	Deltamethrin (2.5% EC)	89%	–
Chemical	Chlorpyrifos (48% EC)	85%	–
Biological	*Metarhizium acridum* (IMI 330189)	45%	74%

Statistical analysis using RStudio (ANOVA and chi-square tests) confirmed significant variation in infestation levels across years ($p < 0.05$), and treatment effectiveness varied according to species composition, life stage targeted, and environmental factors. The data clearly demonstrate the importance of integrating early detection, spatial analysis, and diversified control strategies to manage locust outbreaks in the desertification-prone regions of Eastern Georgia.

Conclusions

The multi-year monitoring and control efforts conducted in the arid and semi-arid regions of Eastern Georgia revealed consistent patterns in locust outbreaks and demonstrated the efficacy of integrated management strategies. Among the identified species, *Calliptamus italicus* remained the most dominant and economically significant, particularly in unmanaged rangelands of Kakheti and Kvemo Kartli. The spatial distribution and infestation severity varied annually, influenced by climatic conditions, especially rainfall variability and vegetation dynamics, as evidenced by NDVI trends.

Systematic monitoring using standardized field protocols and georeferenced tools enabled precise assessment of locust densities and early detection of high-risk zones. GIS-based spatial analysis further improved the visualization of infestation hotspots, supporting timely intervention planning and resource allocation.

Control measures combining chemical and biological approaches yielded effective results. Chemical treatment with ULV insecticides showed high short-term efficacy, particularly in densely infested areas, while biological control using *Metarhizium acridum* demonstrated promising results in ecologically sensitive habitats, with reduced environmental impact. The integration of biological control into locust management is a valuable complement to chemical methods, especially for long-term sustainability.

Statistical analysis confirmed the year-to-year variability of infestation levels and highlighted the importance of continuous monitoring, adaptive strategies, and data-driven decision-making. The results underscore the significance of maintaining and enhancing national locust surveillance and early warning systems, with continued support for capacity building and regional cooperation, particularly within the FAO-led regional framework.

Overall, the study provides a practical model for locust risk management in arid ecosystems, emphasizing the importance of integrated approaches that combine field surveillance, geospatial analysis, and environmentally sound control methods.

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კალიების გავრცელების დინამიკა და ინტეგრირებული მართვის სტრატეგია აღმოსავლეთ საქართველოს არიდულ ზონებში

ნიკოლოზ მესხი, მირანდა წეროძე

რეფერატი

ნაშრომი წარმოადგენს 2011-2023 წლების სისტემურ კვლევას აღმოსავლეთ საქართველოს არიდულ ზონებში გავრცელებული კალიების ეკოლოგიისა და ინტეგრირებული მართვის სტრატეგიების შესახებ. მრავალწლიან მონიტორინგზე დაფუძნებით გამოვლენილ იქნა ორი ეკონომიკურად მნიშვნელოვანი სახეობა იტალური *Calliptamus italicus* და მაროკოული (*Dociostaurus maroccanus*) კალია. მათ შორის მეტად გავრცელებული და დამაზიანებელი აღმოჩნდა იტალიური კალია (*C. italicus*), რომელიც ძირითადად დაფიქსირდა დედოფლისწყაროს, საგარეჯოსა და გარდაბნის მუნიციპალიტეტის ტერიტორიაზე. კვლევა მოიცავდა ფართომასშტაბიან საველე მონიტორინგს (35,000–40,000 ჰა წელიწადში), კოორდინირებული მეთოდებით (კვადრატული და ტრანსექტური გათვლები) ნიმუშების აღებას, GIS ტექნოლოგიებით ინფექციის ზონების რუკების შექმნას და გარემოსთან კავშირის ანალიზს კლიმატური ფაქტორების გათვალისწინებით. ჩატარებულ იქნა წამლობითი ღონისძიებები, როგორც ქიმიური (Deltamethrin, Chlorpyrifos), ისე პილოტურად (300-500 ჰა ფართობზე) ბიოლოგიური (*Metarhizium acridum*) საშუალებებით, რომელთა ეფექტურობა 74-98%-ის ფარგლებში მერყეობდა. სტატისტიკურმა ანალიზმა წლების მიხედვით აჩვენა მავნებლის გავრცელების მნიშვნელოვანი განსხვავებები ($p < 0.05$), რაც კლიმატურ პირობებსა და სახეობრივი დინამიკის ცვლილებებს უკავშირდება. ინტეგრირებული მართვის ღონისძიებებმა, რომელიც მოიცავდა მავნებლების ადრეულ გამოვლენას, ზონალური რუკების შედგენას და მიზნობრივ მკურნალობას, მნიშვნელოვნად შეამცირა მოსავლის დანაკარგები. წარმოდგენილი მონაცემები ადასტურებს, რომ კალიების საწიონააღმდეგო ღონისძიებების ეფექტიანი მართვა საჭიროებს მრავალწლიან, ინტეგრირებულ სტრატეგიებს, რომლებიც აერთიანებს ტექნოლოგიურ, ქიმიურ და ბიოლოგიურ კომპონენტებს, განსაკუთრებით კლიმატურად მოწყვლად რეგიონებში, როგორიცაა აღმოსავლეთ საქართველოს არიდული ზონა.

საკვანძო სიტყვები: *Calliptamus italicus*, კალიების ინტეგრირებული მართვა, არიდული ზონები.