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A CITIZEN SCIENCE INITIATIVE FOR LONG-TERM ENGAGEMENT IN CONSERVATION OF AGROBIODIVERSITY ON-FARM: A CASE STUDY OF NEST

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Abstract

Modern agriculture, which promotes the development of new varieties with a narrow genetic base and relies on controlled seed production, has caused a significant loss of farmland biodiversity. The "Women Netting for Seed Treasure Revival (NEST)" initiative aims to promote the sustainable cultivation of local old varieties through a participatory citizen science approach. Its key activities include inventorying traditional varieties grown on farms and training farmers in seed collecting, handling, and conservation. By fostering active collaboration among scientists, volunteers, and farmers, the initiative aims to strengthen the role of women in agriculture. Preserving their traditional knowledge—as crucial for mitigating farmland biodiversity loss and addressing climate change—opens new avenues for innovative scientific approaches. Through participatory citizen science, the project aims to bridge the gap between scientists and local communities, facilitating the conservation and exchange of traditional old varieties seeds, safeguarding farmland biodiversity, and ensuring food security.

Key words: community engagement, farmland biodiversity, participatory citizen science, seed conservation, sustainable agriculture, traditional old variety, women's entrepreneurship

Introduction

Agricultural biodiversity, which has significant social, cultural, economic, and environmental implications, includes all aspects of biological diversity relevant to food and agriculture, as well as those that comprise agricultural ecosystems (Hailu, 2025). It not only provides food, income, and raw materials for various purposes, but it also performs vital ecological services such as soil fertility and biota maintenance, as well as soil and water conservation—all of which are necessary for human survival (Corrado et al., 2019; Maskell et al., 2023).

Studies consistently show that rich agrobiodiversity plays an essential role in ensuring food security. As a result, researchers in ecology, resource management, and agriculture have become increasingly interested in developing strategies to conserve agricultural biodiversity. However, global climate change poses serious challenges to agricultural biodiversity conser-

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vation (Yang et al., 2024), and farmers whose primary source of income is agriculture are particularly vulnerable to these changes. Accordingly, climate-smart varieties are vital for farmers' economic stability and agroecosystem resilience. Traditional varieties, shaped by long-term natural and artificial selection pressures, frequently exhibit excellent resilience to climate and soil conditions altered by climate change, including cold and drought conditions (Arca et al., 2021), and play an important role in crop breeding (Mladenović Drinić and Savić Ivanov, 2017; Balconi et al., 2024).

Moreover, traditional agricultural practices that conserve biodiversity are often deeply intertwined with local cultures (Yuan et al., 2014; Caballero-Serrano et al., 2019; Ma et al., 2021). These practices typically involve unique traditions, skills, and methodologies associated with cultivating specific varieties. Such knowledge forms an essential part of local cultural heritage (Yang et al., 2017). However, growing population demands for increased food production have led many farmers to adopt modern varieties and agricultural practices, often at the expense of traditional varieties. This shift results in the erosion of agricultural genetic diversity, along with the disappearance of related traditional knowledge, skills, and cultural practices (Thormann and Engels, 2015).

Safeguarding indigenous knowledge and traditional agricultural practices is essential for the conservation of local crop varieties and farmland biodiversity, which in turn supports food security. Given the deep-rooted connection between traditional cultural heritage and agrobiodiversity, both of which are integral components of daily life, capitalizing on the recent expansion of citizen science for monitoring farmland biodiversity offers a promising approach to addressing these interconnected challenges (Figure 1) (Chandler et al., 2017; Billaud et al., 2021).

Utilizing a participatory citizen science approach, this case study of the NEST project examines strategy to address farmland biodiversity loss by engaging local communities and farmers, with a particular focus on women farmers, to promote the conservation of traditional crop varieties, enhance climate resilience, and preserve cultural heritage.

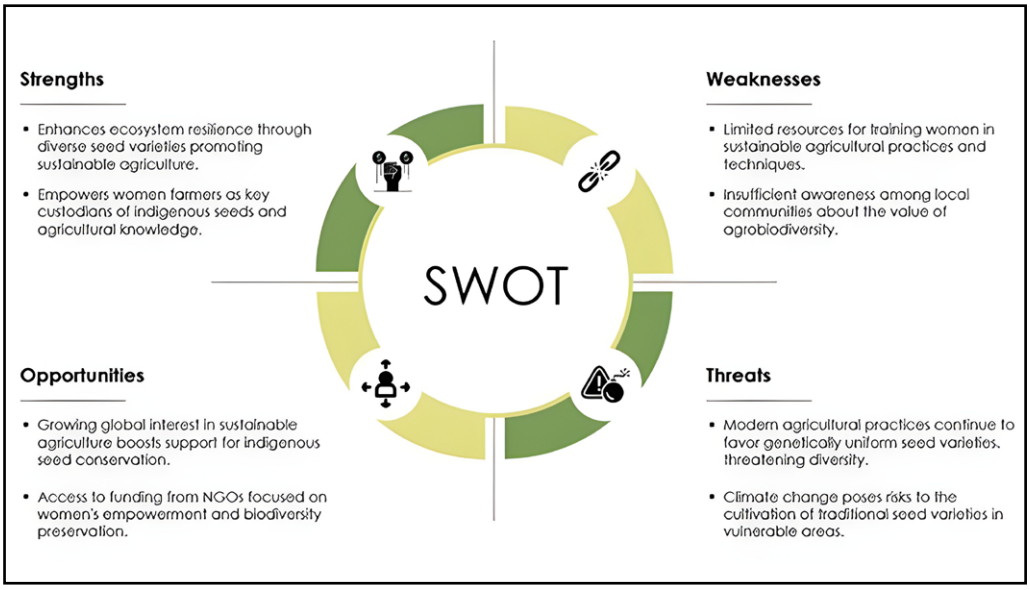

Figure 1. SWOT analysis
Grafikon 1. SWOT analiza

Conceptual framework

Citizen science, a collaborative method of volunteering that involves non-experts in scientific research, has seen a significant rise in popularity over the past twenty years (Tulloch et al., 2013; Bonney et al., 2014). This participatory approach encourages interactions between researchers and citizens, often leading to innovative changes in research methodologies and results (van de Gevel et al., 2020). Although citizen science covers a broad spectrum of research practices worldwide, it is especially prominent in environmental sciences, such as ecology and conservation (Cooper et al., 2010; Froeling et al., 2021). Conversely, a smaller proportion of published citizen science studies focus on more applied fields like food and agriculture (Kullenberg et al., 2016; Ryan et al., 2018). Agricultural citizen science projects tend to be longer-term and require active citizen involvement at various stages. Consequently, the success of these initiatives heavily depends on sustained participation and engagement from citizens.

Technological advancements have reduced the barrier to participation; however, recruitment and retention remain challenges in citizen science (Frensley et al., 2017; Tang et al., 2019). Participation is a complex concept with multiple levels that represent a citizen's involvement in a citizen science project. These levels are frequently influenced by various factors (West et al., 2016; Fisher et al., 2021). By distinguishing between participation levels during project evaluation, it becomes possible to investigate the specific drivers that influence each level (Fisher et al., 2021). Overall, research has highlighted the importance of a desire for learning and understanding, a commitment to conservation, and personal values as key motivators for participation in environmental citizen science projects (Domroese and Johnson, 2017; Larson et al., 2020; Maund et al., 2020; Etter et al., 2023).

Underlying principles

The intersection of citizen science, volunteering, and pro-environmental actions

Citizen science involves the active participation of non-specialists, volunteers, in generating new scientific knowledge, often in collaboration with professional scientists (Bonney et al., 2014). This engagement encompasses a range of responsibilities, including data collection and the co-development of research methods, all while adhering to scientific standards. Similar approaches are observed worldwide under terms such as "community science" and "community-based research," which include activities from large-scale data gathering to independent research conducted by non-academic associations (Jaeger-Erben et al., 2023). In the NEST initiative, participants primarily focused on collecting data and producing scientifically valuable results, a form of citizen science known as "crowdsourcing" (Vanden Berghen et al., 2024) (Figure 2).

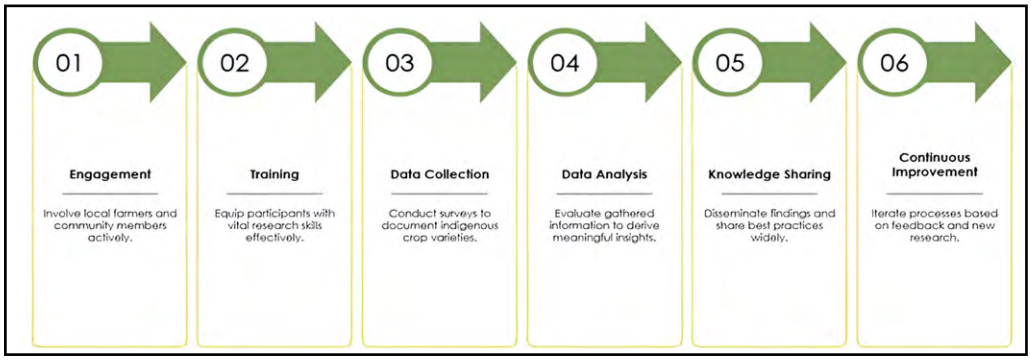

Figure 2. Participatory citizen science approach
Grafikon 2. Principi participativne građanske nauke

Moreover, participation in citizen science projects highlights the significant overlap between agricultural citizen science and pro-environmental behaviour, as these initiatives frequently involve individuals in activities that promote environmental sustainability (Ebitu et al., 2021; Mourad et al., 2020). By engaging in agricultural citizen science efforts, individuals not only contribute to scientific knowledge and innovation but also actively support sustainable farming practices, biodiversity conservation, and resilient food systems (Ryan et al., 2018). This demonstrates the vital role citizen science plays in fostering both scientific exploration and environmentally conscious actions within agriculture, as well as its potential to address current agricultural challenges.

Assessing contributors involvement in citizen science initiatives

Active volunteers' engagement is essential for the successful functioning of any association that relies on their efforts. In the literature on volunteering, two terms are encountered: "initial participation"—pertaining to recruitment and help in identifying factors that differentiate participants from non-participants, e.g., "sustained participation"—relating to retention and the ongoing level of commitment that volunteers maintain (Penner, 2002). Similar to volunteering, recruiting and retaining citizens are essential for the success of participatory research initiatives. Within the frame of volunteer retention, various levels of participation in citizen science initiatives have been identified (Tiago et al., 2017; Fisher et al., 2021; Vlaminck et al., 2024). Based on motivation and engagement, three groups of citizen science participants have been reported: "dropouts", "dabblers", and "super-users" (Vlaminck et al., 2024). Moreover, the dropout rates classified the participants according to their level of involvement: "never participating", "occasional participation", "regular participation", and "frequent participation" (Tiago et al., 2017). Additionally, the "Nibble-and-Drop" framework was proposed, effectively identifying multiple dropout points and stages of contribution typical for participation in citizen science projects (Fisher et al., 2021).

Motivations behind citizen science participation

Motivation is the primary feature of both initial and sustained citizen science participation (Alender, 2016; Aitamurto et al., 2017; Tiago et al., 2017; Vlaminck et al., 2024), and it is defined as the subjective reason that people claim or recognize as driving their behaviour (Aitamurto et al., 2017).

The Volunteer Functions Inventory (VFI), a widely used tool for understanding the motivations behind volunteering, identifies six primary functions that explain why individuals choose to volunteer: values, understanding, enhancement, career, social, and protective functions (Clary et al., 1998). Studies utilizing the VFI to explore motivations for participating in citizen science consistently demonstrate that the "values" function is the primary driver of initial engagement. This suggests that people are mainly motivated by an intrinsic desire to express their altruistic beliefs through citizen science activities (Alender, 2016; West and Pateman, 2016; Maund et al., 2020). Moreover, sustained participation in citizen science has been linked to motivations such as acquiring knowledge, skills, and abilities ("understanding"), as well as expressing altruistic and humanitarian values ("values") (Cox et al., 2018; Maund et al., 2020). Research on how motivations evolve over time highlights the importance of aligning initiative goals with participants' core values and interests while also considering how socioeconomic and cultural factors influence long-term involvement (Lopez, 2021).

In studies examining motivations for environmental volunteering, environmental concern has also emerged as a key factor driving increased participation in citizen science initiatives (West et al., 2021). According to theory, when individuals are more aware of environmental issues and recognize the importance of addressing them, especially when environmental protection aligns with their personal values, they are more likely to take action (Binder and Blankenberg, 2016; Ngo et al., 2023). Citizen science provides a tangible way for people to contribute to scientific research and sustainability

efforts, enabling active engagement in tackling environmental challenges. Additionally, numerous studies have underscored the complex ways in which moral imperatives motivate individuals to dedicate time and resources to volunteer work and pro-environmental behaviours (Ateş, 2020). This highlights the significant role of moral obligation and a sense of responsibility in shaping people's involvement in citizen science.

Factors influencing participation in citizen science initiatives

In the literature on volunteering, it is frequently observed that, although the motivation to engage in volunteer activities may be present, the decision to participate in a specific initiative often depends on its compatibility with an individual's lifestyle (Mourad et al., 2020). According to Penner (2002), this compatibility is shaped by "dispositional variables," which include personal attributes such as values, beliefs, and knowledge that influence an individual's propensity to volunteer, as well as demographic factors like age, income, and education (West and Pateman, 2016; Mourad et al., 2020). Therefore, these dispositional variables can affect both the motivation to volunteer and the likelihood of actual participation. Furthermore, although prior volunteer experiences can potentially enhance the probability of future engagement, the overall quality of these experiences remains an important issue (Hamilton and Fenzel,1998; Niebuur et al., 2018).

The NEST initiative: A case study of participatory approaches and implementation

The two-year NEST project (https://www.dsss.org.rs/nest/index.php), funded under Grant No. 1377/24, has been chosen as one of the winning proposals (https://www.cpn.edu.rs/dodela-priznanja-dobitnicima-drugog-javnog-poziva-za-projekte-gradjanske-nauke/?script=cir) in the public call for citizen science research projects organized by the Center for the Promotion of Science, which is part of the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia.

By applying a participatory citizen science approach to promote the conservation of traditional old varieties and sustainable farming practices, the NEST initiative contributes to mitigating farmland biodiversity loss. It emphasizes the empowerment of women in agriculture by integrating culturally relevant practices, agricultural heritage and traditional knowledge. Central to this approach is the formation of a collaborative network of scientists, citizen volunteers, and farmers to inventory and document locally cultivated traditional old varieties, facilitate seed conservation, and disseminate knowledge about farmland biodiversity and sustainable farming practices. Furthermore, the initiative aims to establish a communication network for seed and information exchange, demonstrating its commitment to a transdisciplinary framework (Figure 3). This multifaceted strategy includes direct farmer participation in training and information exchange, active citizen volunteering in data collection, and expert leadership throughout the entire collaborative effort. Recognizing the pivotal role women play as custodians of indigenous varieties and traditional agricultural practices, the project supports women's economic independence by encouraging entrepreneurship related to the cultivation of traditional old varieties and their placement in the market. To foster community building and disseminate the achievements and information, the project utilizes workshops, community events, and a dynamic online seed inventory database and communication forum, strongly confirming the commitment to an open science approach that encourages transparency and accessibility in research.

By engaging local communities, particularly women, in data collection and educational initiatives, NEST protects farmland biodiversity and enhances economic independence and community resilience. This holistic approach aligns with sustainability goals and fosters collaboration among scientists, volunteers, and farmers to confront the challenges of biodiversity loss and climate change. Focused on education, research, dissemination, and project management,

Figure 3. NEST project activities overview
Grafikon 3. Pregled aktivnosti projekta NEST

NEST aims to create lasting impacts on agriculture and conservation. The NEST reinforces the importance of local actions in a global context and creates valuable data resources, aligned with vital sustainable development goals (SDGs): zero hunger (SDG 2), gender equality (SDG 5), climate action (SDG 13), and life on land (SDG 15), thus affirming its holistic approach to sustainability (Figure 4).

Structured into four working packages (WPs), the project depicts its practical implementation as follows:

WP1—Knowledge Sharing, Education, and Networking, aims to empower local communities to actively engage in agro-biodiversity research and to transform them into "living labs." Qualified volunteers will contribute to advancing farmland biodiversity conservation, sustainable agriculture, and food security within a structured framework that encompasses the development of clear selection criteria, comprehensive training programs, and skill enhancement for citizen scientists. This framework utilizes accessible manuals and video tutorials on research methodologies and data management to facilitate learning. Additionally, this well-structured framework will establish extensive networks and communication channels, online forums for experience exchange and Q&A sessions, among citizen scientists (Figure 5). Special emphasis will be placed on highlighting and supporting the pivotal role of women in the preservation of seed biodiversity.

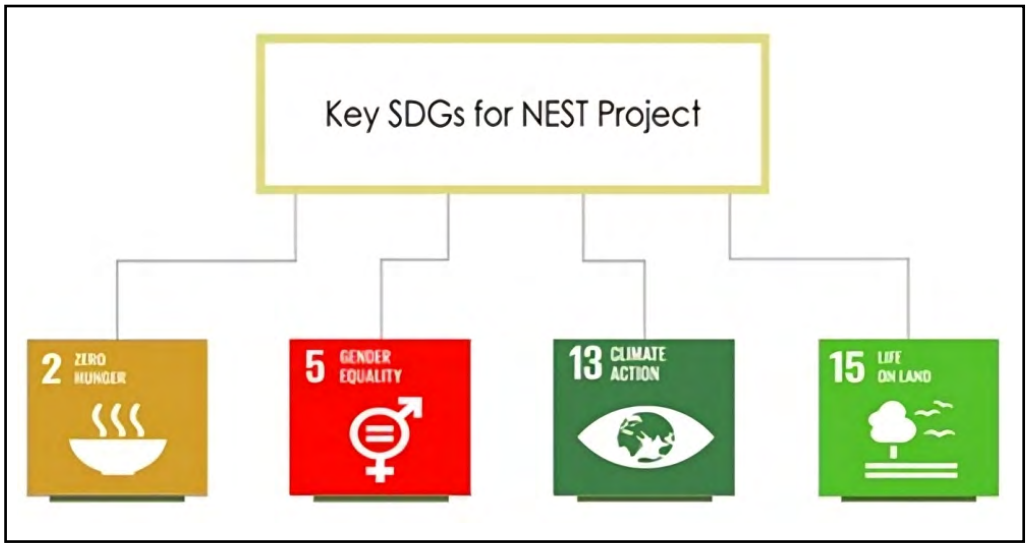

Figure 4. Essential sustainable development goals for NEST
Grafikon 4. Osnovni ciljevi održivog razvoja za NEST

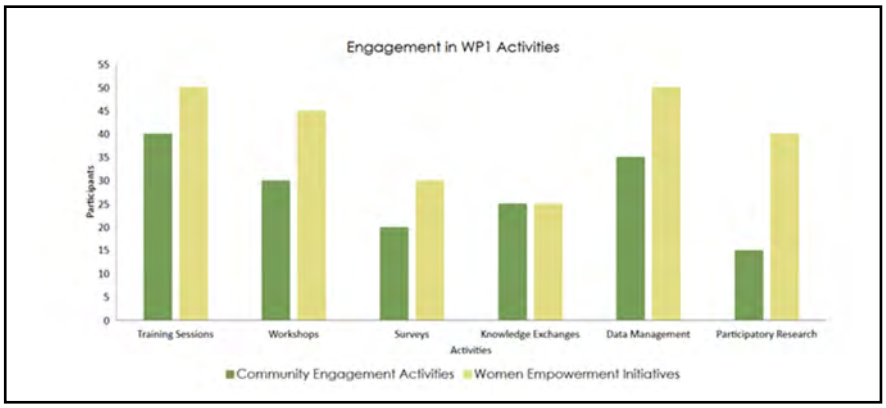

Figure 5. Knowledge sharing, education, and networking
Grafikon 5. Razmena znanja, edukacija i umrežavanje

WP2—Research Activities of Citizen Volunteers for Enhancing Farmer Motivation, aims to empower farmers, particularly women, by leveraging citizen science approaches to document and promote the cultivation and utilization of local, traditional crop varieties within rural communities. Under the guidance of NEST researchers, citizen volunteers will conduct comprehensive farm surveys to inventory traditional local varieties and analyse the socioeconomic structure of agricultural households, with a particular emphasis on women's roles. The collected data will be used to improve targeted education and training programs for female farmers, with a focus on seed conservation, sustainable agricultural practices, and genetic diversity preservation. The findings and outcomes of these activities will be disseminated through workshops, lectures, and community gatherings involving project participants and volunteers. Creating networks to facilitate seed exchange between farmers and relevant organizations is an important aspect of this work. Additionally, volunteer performance will be assessed based on the following metrics: motivation, knowledge acquisition, and operational efficiency (Figure 6).

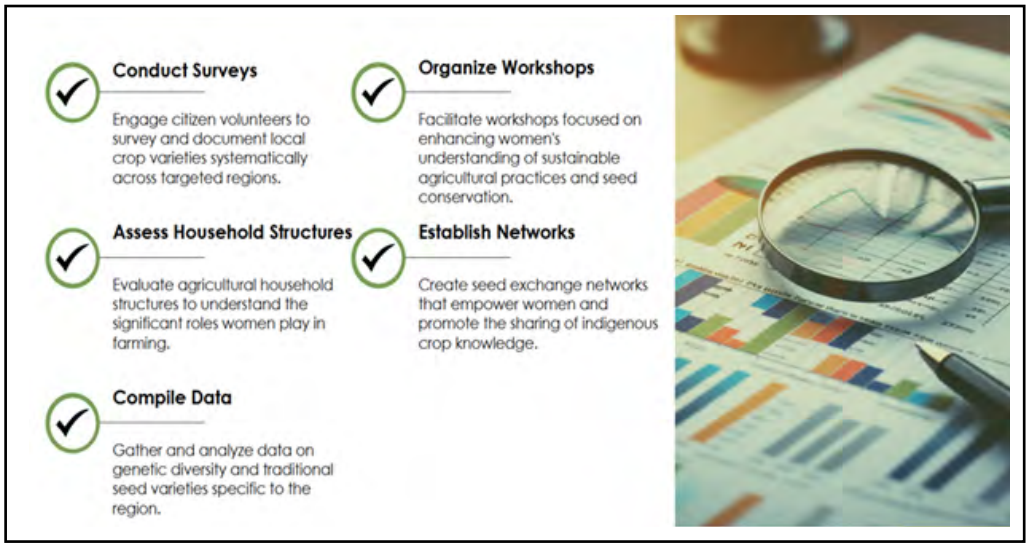

Figure 6. Research activities of citizen volunteers for enhancing farmer motivation
Grafikon 6. Istraživačke aktivnosti građana volontera za poboljšanje motivacije poljoprivrednika

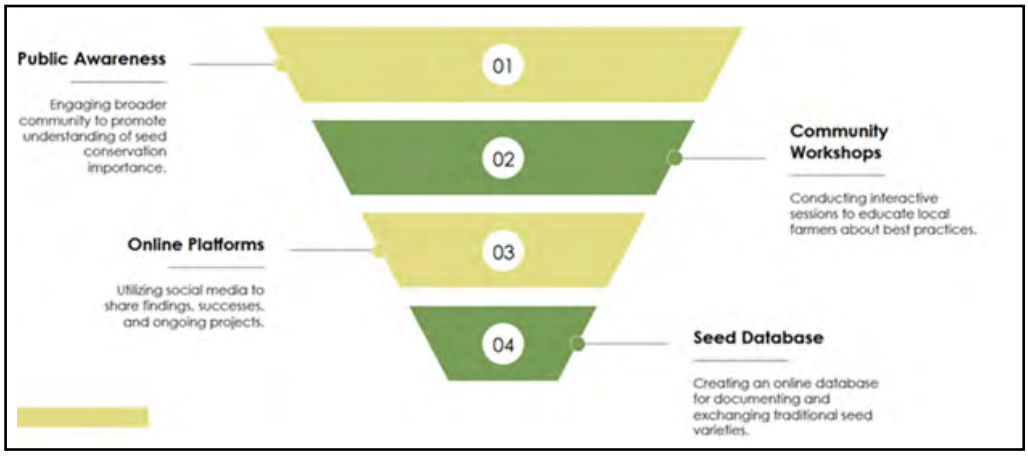

Figure 7. Dissemination of project's goals and achievements
Grafikon 7. Širenje informacija o ciljevima i dostignućima projekta

WP3—Dissemination, intends to actively promote the project's goals and achievements by involving all project participants, scientific institutions, the association of plant breeders and seed producers, and citizen volunteers. This will be achieved through social media outreach, events, lectures, the development of a seed database, study visits, and a closing conference. The main objective of WP3 is to build a network of citizen researchers, foster innovative initiatives, support farmer engagement, and promote sustainable agriculture. Special emphasis will be placed on highlighting the vital role of women in preserving traditional old varieties. Additionally, the project will encourage variety cultivation and seed exchange practices. Study visits to breeding institutes, national seed gene banks, and specialized centres within agricultural and food agencies will serve as models to educate women in rural areas on best practices in cultivation, conservation, and entrepreneurship (Figure 7).

WP4—Project Management, ensures project success by facilitating cooperation and activity coordination. It employs project management tools, clear communication, supervision, and guidance to manage the project's implementation and coordinate the preparation and submission of all required reports. Regular project meetings are held to monitor progress and implement corrective actions (Figure 8).

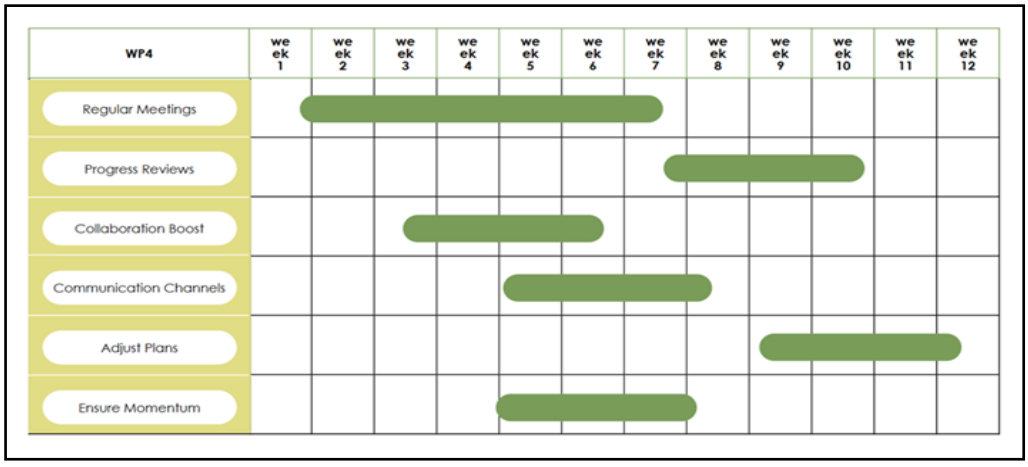

Figure 8. Project management
Grafikon 8. Upravljanje projektom

Research aims and scientific disciplines underpinning the NEST initiative

The NEST initiative bridges multiple scientific disciplines, primarily rooted in agricultural science and sustainability studies. Its focus on crop cultivation, sustainable farming practices, and food security aligns closely with research areas such as conservation biology, ecology, plant genetics, and breeding. Key goals include preserving farmland biodiversity and addressing environmental challenges like biodiversity loss and climate change adaptation, core concerns within conservation biology and ecology. The project's emphasis on the genetic diversity of traditional old varieties is particularly connected to research in plant genetics and breeding. In addition, the active participation of citizens in scientific research integrates social science methodologies, including community engagement and participatory research approaches. The promotion of sustainable practices, economic independence, and women's entrepreneurship underscores the project's relevance to agricultural economics and rural development. Its training and knowledge-sharing components further relate to educational and outreach strategies.

The central research question explores how a participatory citizen science approach can contribute to conserving farmland biodiversity and ensuring food security. Specifically, the project aims to investigate (1) how citizen involvement can enhance seed conservation of traditional old varieties; (2) effective methods for training and empowering women farmers in seed conservation and sustainable practices; and (3) ways to integrate women's traditional agricultural knowledge with scientific research to combat farmland biodiversity loss and adapt to climate change. Ultimately, the initiative seeks to raise awareness of plant genetic resources, strengthen women's economic independence, and establish networks and platforms to support women entrepreneurs while documenting existing farmland biodiversity inventories.

Key organizations and participants in the initiative

To combat farmland biodiversity loss and promote sustainable agriculture, the NEST initiative involves scientific institutions—the Maize Research Institute Zemun Polje (https://mrizp.rs), which provides expertise in genetic resources; the Institute for Plant Protection and Environment (https://izbis.bg.ac.rs), which trains volunteers in seed conservation; and the Serbian Association of Plant Breeders (https://www.dsss.org.rs), which coordinates outreach and capacity building, especially for women in rural areas. Citizen scientists (volunteers) collect data and educate communities on biodiversity, while farmers, particularly women, maintain traditional varieties. Local governments support community engagement and sustainable policies, working together to preserve biodiversity and strengthen local practices.

Citizen engagement—A profile of the citizen scientists community and its role in the NEST initiative

The NEST community of citizen scientists is recruited using well-established procedures to ensure broad and diverse involvement. These recruitment strategies rely on public campaigns appearances, social media outreach, and local events, to attract a diverse spectrum of volunteers, community members, and farmers, particularly focusing on female farmers' involvement. Once interested volunteers express their willingness to participate, they undergo a structured registration process that assesses their motivations, communication skills, and educational backgrounds in agriculture, biology, engineering, and sociology, as well as their understanding of biodiversity conservation. This procedure aids in the formation of a representative, broad demographic volunteer group that comprises both enthusiastic students eager to explore scientific and environmental challenges, as well as elder individuals or retirees who provide valuable experience and mentorship. Furthermore, the NEST initiative also actively involves local women's associations and self-governing bodies to foster community engagement.

Following registration, citizen volunteers receive training in seed management, seed collecting, storage, and conservation practices. Focusing especially on female farmers, they implement educational initiatives on farmland biodiversity, conservation methodologies, and

sustainable farming practices and are in charge of collecting data on local traditional varieties grown on farms, as well as monitoring and reporting on plant genetic resources. In addition, citizen scientists facilitate the creation of communities' seed-exchange networks to support seed sharing and conservation efforts. They work closely with researchers to strengthen the link between scientific knowledge and local agricultural practices, ensuring that conservation initiatives are relevant, practical, and community-centred. This integrated approach aims to promote the sustainable management of plant genetic resources, ultimately contributing to agro-biodiversity preservation and resilient agricultural systems.

Beyond the NEST: From community innovation to lasting legacy

The NEST project aims to establish community seed libraries, facilitating seed sharing among farmers. This innovative system allows farmers to borrow and return seeds, promoting biodiversity while reducing reliance on commercial seed sources. Additionally, NEST intends to engage farmers in participatory breeding initiatives to grow varieties tailored to local needs for enhanced resilience to climate change. To support collective marketing, resource sharing, and collaborative decision-making, especially among female farmers, NEST encourages the formation of cooperatives. These cooperatives will strengthen community resilience and pave the way for certification programs that recognize and support farmers using traditional methodologies, ultimately improving market access and enabling higher prices for sustainably produced varieties. In addition, NEST aims to integrate farmland biodiversity education into school curricula, nurturing environmentally conscious future generations. The project also intends to collaborate with universities and research institutions to secure scientific expertise, resources, and funding, thereby enhancing its credibility and reach. Partnerships with local governments and NGOs will provide financial and technical incentives for sustainable farming practices.

By integrating these strategies, NEST comprehensively promotes the preservation of farmland biodiversity and empower local communities, creating lasting impacts on agriculture and conservation efforts.

Conclusion

The conservation of farmland biodiversity is fundamental to ensuring food security, ecological sustainability, and the preservation of cultural heritage, especially amidst increasing threats from climate change and modern agricultural practices. Traditional crop varieties and indigenous knowledge are crucial for resilient agroecosystems and cultural identities, yet these resources are under growing pressure due to the widespread adoption of uniform, industrialized agricultural systems driven by demographic and market demands.

Participatory citizen science presents a promising approach to addressing these pressing challenges. Initiatives like NEST exemplify how engaging local communities, particularly women farmers, can leverage indigenous knowledge and sustainable practices to protect traditional crop varieties and bolster the resilience of agroecosystems. Through active involvement, communities can enhance environmental awareness, reinforce cultural identities, and contribute to sustainable agricultural development. Such projects also demonstrate that empowering communities to participate in scientific research is vital for conserving biodiversity and building resilient, culturally aligned food systems.

The success of these efforts depends on understanding what motivates citizen participation, often rooted in intrinsic values, environmental concern, and moral responsibility, and addressing factors that influence long-term engagement. Recognizing these motivators can improve recruitment and foster sustained involvement. Ultimately, integrating citizen

science into conservation strategies not only safeguards traditional knowledge and cultural heritage but also promotes the development of resilient, sustainable food systems that meet environmental challenges and respect local values.

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Author contributions

Conceptualization, N.K. and M.T.; Methodology, V.B., V.P. and M.T.; Software, M.T.; Data curation, I.Ž. and M.T.; Investigation, V.B., V.P., I.Ž. and M.T.; Resources, N.K., V.B. and V.P.; Project administration, M.T.; Supervision, N.K.; Visualization, I.Ž., V.O. and D.S.; Validation, V.P., V.O. and D.S.; Funding acquisition, M.T.; Writing — original draft, N.K.; Writing — review & editing, V.B.

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INICIJATIVA GRAĐANSKE NAUKE ZA DUGOROČNO UKLJUČIVANJE U OČUVANJE AGROBIODIVERZITETA NA FARMAMA: STUDIJA SLUČAJA NEST-A

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Sažetak

Savremena poljoprivreda promoviše razvoj novih sorti uske genetičke osnove i oslanja se na kontrolisanu proizvodnju semena, čime je uzrokovala značajan gubitak biodiverziteta u poljoprivredi. NEST inicijativa ima za cilj da podstakne održivo gajenje lokalnih starih sorti poljoprivrednih biljaka, putem participativnog pristupa građanske nauke. Ključne aktivnosti projekta NEST uključuju popis tradicionalnih sorti koje se gaje na farmama, kao i obuku poljoprivrednih proizvođača u sakupljanju, rukovanju i čuvanju semena. Podsticanjem aktivne saradnje naučnika, volontera i poljoprivrednika, inicijativa teži jačanju uloge žena u poljoprivredi. Očuvanje njihovog tradicionalnog znanja, koje je ključno za ublažavanje gubitka biodiverziteta na poljima i odgovor na izazove klimatskih promena, otvara nove puteve za inovativne naučne pristupe. Kroz participativni pristup građanske nauke, NEST ima za cilj da premosti jaz između naučnika i lokalnih zajednica, olakšavajući očuvanje i razmenu starih tradicionalnih sorti, čime se štiti biodiverzitet poljoprivrednog zemljišta i obezbeđuje dovoljna količina hrane.

Ključne reči: angažovanje zajednice, biodiverzitet poljoprivrednog zemljišta, participativna građanska nauka, očuvanje semena, održiva poljoprivreda, tradicionalna stara sorta, žensko preduzetništvo

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