RESEARCH ARTICLE Bhartiya Krishi Anusandhan Patrika, Volume 41 Issue 1: 78-84 (March 2026)

Regenerative Agriculture as Nature based Solution in Urban and Peri-urban Bengaluru: Knowledge, Practices and Value

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10.18805/BKAP914

ABSTRACT

Background: Regenerative agriculture forms the foremost Nature-based Solution for improved environmental health. This study examines the regenerative agriculture (RA) methods adopted by farmers in and around Bengaluru and evaluates their ecological and economic value.

Methods: Fifteen farms were studied using semi-structured interviews and soil nutrient analysis. The farms employed a diverse set of practices centered on five core RA approaches that integrate traditional knowledge with contemporary techniques.

Result: The farms adopted diverse NbS including cover cropping, companion cropping and nature-friendly pest management practices, along with innovative marketing strategies and diversified farm-based income sources. Soil analysis indicated significantly enhanced soil organic carbon (SOC) levels, often exceeding the national average of 0.3% and macro- and micronutrient concentrations that were 1-10 times higher than the minimum recommended values. Retention of trees and shrubs supported pollinator diversity, while practices such as rainwater harvesting, drip irrigation and soil conservation promoted agricultural sustainability. Farms F7 and F13 exclusively cultivated indigenous and heirloom varieties, practicing seed harvesting and saving. Located in urban and peri-urban Bengaluru, these farms benefited from diversified income streams through value-added products, farm tourism and sustainable agriculture training initiatives. Several important insights emerged on novel urban and peri-urban agricultural systems integrating food, water, ecological, climatic and economic security while connecting multiple stakeholders and consumers.

Key words: Companion cropping, Nature-based solutions, Regenerative agriculture.

INTRODUCTION

Rapid urban expansion to accommodate growing populations has intensified the need for sustainable urban food systems, positioning urban agriculture as an increasingly important resource (Hatab *et al*., 2019). Regenerative Agriculture (RA) enhances the role of urban agriculture by offering healthier food options while creating multifunctional green spaces that support biodiversity, including earthworms, pollinators and birds, which in turn contribute to improved agricultural outcomes (Khangura *et al*., 2023; Kabenomuhangi and Rodgers, 2024). Beyond food production, RA farms in cities provide recreational, educational and wellbeing spaces, offering social and cultural benefits to urban residents (Hawken and Rand, 2014). In contrast, Conventional Agriculture (CA), reliant on chemical fertilizers and pesticides, has been widely documented to degrade ecosystems through biodiversity loss, soil acidification, nitrogen pollution, eutrophication of water bodies, greenhouse gas emissions and adverse health impacts on farmers and consumers (Średnicka-Tober *et al*., 2016).

Sustainable soil management practices characteristic of RA promotes diverse soil microbial communities, enhancing soil carbon sequestration and biological nitrogen fixation, thereby contributing to climate change mitigation in urban and peri-urban landscapes (Ghosh *et al*., 2024; Terlemezyan *et al*., 2025). Urban RA also benefits from proximity to markets, reducing transportation costs and associated carbon footprints. While both CA and RA contribute to urban heat island mitigation through green cover, yet the emission of nitrous oxide and other greenhouse gases from CA can offset these benefits (Kumar and Hundal, 2016; Banerjee *et al*., 2023).

Despite increasing policy support in India for nature-friendly farming transitions, limited empirical research exists on how RA functions within urban and peri-urban contexts, particularly in terms of farming practices, livelihoods, markets and economic viability. Addressing this gap, the present study investigates regenerative agriculture farms in urban and peri-urban Bengaluru. The research

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How to cite this article: Vaishnavi, V., Reddy, R., Krishnaswamy, J. and Singh, I. (2026). Regenerative Agriculture as Nature based Solution in Urban and Peri-urban Bengaluru: Knowledge, Practices and Value. *Bhartiya Krishi Anusandhan Patrika.* **41(1):** 78-84. doi: 10.18805/BKAP914.

Submitted: 09-01-2026 **Accepted:** 25-02-2026 **Online:** 13-03-2026

aims to assess the range of RA practices adopted, associated livelihood opportunities, market linkages and economic models supporting farm sustainability, thereby identifying effective practices and pathways for scaling RA within rapidly urbanizing regions.

MATERIALS AND METHODS

Study sites

Fifteen regenerative agriculture farms spread across different parts of Bengaluru-urban and peri-urban regions were identified for this study. The farms were in Bengaluru district's - Varthur Post, Whitefield, Hennur, Sarjapur, Bidadi, Hoskote, Hunasur, Anekal, Vidyaranyapura, Maralakunte, Bagalur and one in the neighbouring district of Mysuru.

Farm surveys

Comprehensive surveys and interviews were conducted across the 15 regenerative agriculture farms to document farming practices related to soil and crop management, pest control, water-use strategies, seed type and sourcing, market channels, farm-based income diversification and supported livelihoods. A structured questionnaire was developed to capture data on agricultural practices, labour, water use, crop productivity, biodiversity, markets, associated costs and economic aspects. The study also examined the interacting socio-ecological factors contributing to farm-level success.

Soil sampling and nutrients profiling

Soil sampling plots were selected based on crop cultivation areas. Soil was collected from the rhizosphere at a depth of 1-5 cm, with samples taken from four corners and the center of each plot and pooled to obtain a composite sample of 1-1.5 kg for nutrient analysis. Samples were analyzed for pH, electrical conductivity, organic carbon and major (N, P, K) and minor (Mg, Ca, Fe, Mn, Zn, Cu) nutrients using established protocols (Singh *et al*., 2023). Soil sulphur content was determined using the turbidimetric method (Black *et al*., 1965).

RESULTS AND DISCUSSION

Agricultural practices

We found that the farms implemented a diverse set of biodiversity-friendly agricultural practices. The soil and crop management practices aligned with one or more primary regenerative agriculture approaches:

I. Fukuoka Method/Permaculture (FM), which emphasizes on minimal intervention, no-till, natural seed-dispersal and natural multi-crop led pest control (Fukuoka, 1985).
II. Subhash Palekar Natural Farming (SPNF/ZBNF), relying on cow dung and cow urine based microbial formulations, intercropping and mulching to enhance soil microbiota and no chemical inputs (Mandla and Sharma, 2022).
III. Narayan Reddy Method (NRM), integrating traditional agronomic practices with sustainable techniques such as organic matter recycling, crop rotation and polyculture (Reddy, 2011).
IV. Charles Dowding Method (CDM), a no-dig approach involving a raised-bed formation using compost and mulch to preserve soil structure and microbial activity (Dowding, 2013).
V. Integrated Method (IM), combining elements of the above approaches based on farm-specific needs.

Of the 15 farms surveyed, three practiced FM, two followed raised-bed cultivation aligned with CDM, one adopted NRM, four implemented SPNF and five practiced IM. Farm-specific variations and distinctive features are summarized in Fig 1.

Farm vegetation and crop diversity

Across the surveyed farms, a wide range of annual crops, vegetables, fruit trees, spices and flowering plants were observed. Several species were repeatedly seen across multiple farms, including *Mangifera indica*, *Cocos nucifera, Musa spp., Solanum lycopersicum, Solanum melongena, Abelmoschus esculentus* and *Carica papaya*. Alongside these commonly occurring plants, each farm also maintained unique crop combinations.

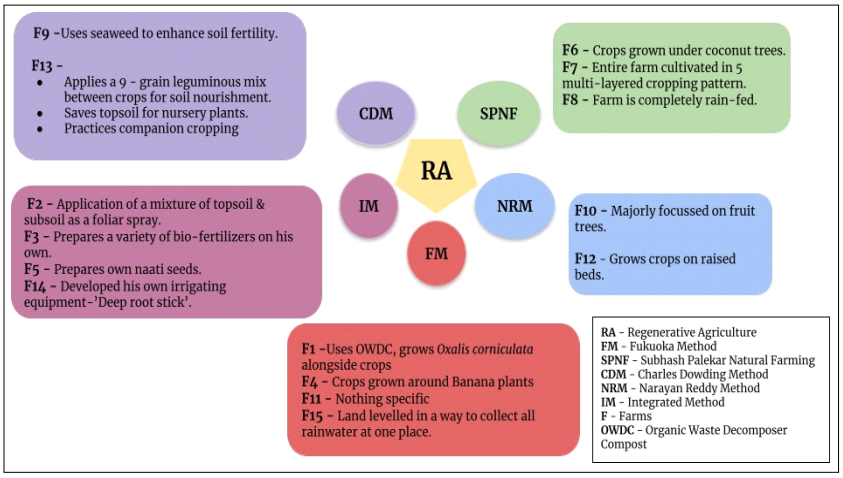


Fig 1: NbS/RA practices implemented for soil and crop management and the specific variations applied by the individual farms.

Soil management practices

The farms used a range of organic fertilisers and soil amendments as nature-based solutions (NbS) to enhance soil biota. Common inputs included cow dung, poultry and goat manure, farmyard mulch and compost, typically applied before sowing. Compost was prepared on-farm using plant residues and cow dung. Several farms also used Organic Waste Decomposer (OWDC), a microbial formulation derived from native Indian cow dung, to accelerate composting or applied directly with irrigation (Kora, 2022).

Plant nutrient inputs included Jeevamrutha (Kumari *et al*., 2022; Amareswari and Sujathamma, 2014), Panchagavya (Singh *et al*., 2023), Fish Amino Acid (Uma and Jeevan, 2022), Effective Microorganism (EM) culture (Javaid and Bajwa, 2011) and fermented buttermilk to enhance microbial activity (Surya and Kaushal, 2021).

Mulching and cover cropping were widely practiced to conserve moisture, suppress weeds and improve soil organic matter. Cover crops such as *Sesbania bispinosa*, *Crotalaria juncea*, *Macrotyloma uniflorum*, *Vigna unguiculata*, *Eleusine coracana, Cajanus cajan* and *Fagopyrum esculentum* were grown to flowering-stage followed by mulching them back to soil, enabling nitrogen fixation, soil carbon enrichment and erosion control (Demo *et al*., 2024; Boateng and Tetteh, 2020). *Trifolium* spp. was intercropped in farm F1 to maintain soil nitrogen levels (Kumar and Goh, 2000). Farm F4 cultivated *Sesbania grandiflora* and *Solanum torvum* on bunds, as an additional income resource owing to their medicinal value.

Pest and weed management

Across all farms, pest management followed a low-intervention, coexistence-based approach, viewing pests as integral components of the agroecosystem and applying control measures only when necessary. Nature-based solutions (NbS) included neem-based products such as neem oil extract and Neem Astra (Vishwakarma *et al*., 2024), along with in-house formulations reported by farm F13, including neem seed and leaf extracts, ginger-garlic-green chilli extract and a five-leaf extract (*Justicia adhatoda, Azadirachta indica, Calotropis gigantea, Morinda citrifolia* and *Vitex negundo*).

Some farms applied Organic Waste Decomposer (OWDC), likely contributing to pest suppression through enhanced proliferation of biocontrol microbes (Gurung, 2023). *Trifolium* spp. was used for weed suppression, indirectly reducing pest pressure, while termite-infested trees were retained for their perceived protective role. Biopesticides such as *Bacillus thuringiensis, Beauveria bassiana, Metarhizium, Pseudomonas, Trichoderma* and *Azotobacter* were widely used, alongside physical controls including sticky, light, solar and pheromone traps. Farm F2 uniquely employed the CVR method, involving foliar application of soil mixtures to enhance plant immunity (Archana *et al*., 2020). Trap cropping with marigold and border crops such as sunflower and sun hemp (F13), as well as seaweed, milkweed sprays and a plant-based weedicide (F10), further supported ecological pest regulation.

Farm irrigation method and water usage

Irrigation practices varied across farms depending on water availability, seasonal conditions and farm-specific constraints. Borewells were the primary water source, with depths ranging from 360 ft (F3) to 1,250 ft (F7), supplemented by groundwater recharge structures such as dugout lakes, ponds, injection wells and rainwater harvesting pits. Rainwater harvesting was practiced by most farms (F4, F5, F6, F7, F8, F9, F10, F12, F13 and F15). Farm F7 reported a notable rise in groundwater levels from 1,250 ft to 100 ft over 13 years, indicating substantial aquifer recharge.

Multiple irrigation methods were employed, including drip, sprinkler, micro-sprinkler, flood and pipe irrigation. Water conservation measures such as half-moon berms and runoff channels were used to enhance soil moisture retention and capture eroded topsoil for reuse. Borewells operated on grid electricity or solar pumps and decentralized water treatment and reuse systems were implemented in select farms (F4 and F12). Farmers reported reduced irrigation requirements and improved soil moisture retention over time under natural farming practices, with irrigation frequency varying seasonally.

Seed source and type

Most farmers sourced seeds locally, while farm F13 relied exclusively on seed harvesting. Farm F7 also practiced seed harvesting but did not depend entirely on it for subsequent crop cycles. Six farms (F1, F5, F7, F13, F14 and F15) maintained on-farm nurseries for seedlings. Prior to sowing, some farmers treated seeds with OWDC, Beejamrutha, or Jeevamrutha to enhance germination, reduce fungal infections and promote early plant growth.

Several farmers reported unsuccessful experiences with hybrid seeds. Common seed sources included locally based, central government-supported institutions and established seed companies. In contrast, farms F7 and F13 exclusively cultivated Naati (indigenous) and heirloom seed varieties and actively engaged in seed conservation by sharing seeds and imparting knowledge on their proper storage for future use.

Markets

Farmers marketed their produce through multiple channels serving local and urban consumers. Online platforms and WhatsApp emerged as key marketing modes, expanding significantly since the COVID-19 period, alongside offline outlets such as organic santhes (markets), farmers' markets and mall-based retail stalls. Additional channels included direct sales through family and community networks, nearby vegetable shops, vendors and Farmer Producer Organizations (FPOs). A few farmers (F7 and F11) sold produce through their own websites or larger platforms such as Amazon and Costco.

The absence of a standardized Minimum Sale Price (MSP) for organic produce was identified as a major challenge, resulting in pricing ambiguities. Most farmers did not pursue organic certification due to perceived limited benefits, while only a few (F1, F8, F12 and F13) held certifications to meet platform or export requirements.

Other income resources

Most farmers reported supplementary income sources beyond primary crop-based income. These included cattle-based livelihoods and value-added farm produce, *e.g.*, F2. Common products included turmeric powder, jaggery, spiced ghee, mango pickles and gooseberry jam. Income diversification also encompassed fish-pond management, terrace gardening services and specialized enterprises such as a Tree-to-Bar cacao processing unit integrating on-site training, farm recreation and accommodation.

Additionally, most farmers conducted workshops, training programs and farm excursions, while others engaged in allied or off-farm activities including teaching, art, stock trading, writing, landscape design, business consulting and farm-based homestays for urban tourism.

Livelihoods that the farms support

Each farm typically employed two to three permanent workers or was managed by a resident family responsible for daily operations, with additional temporary labour hired during peak harvesting periods. Labour availability and reliability were reported as major challenges. Most labourers originated from North Karnataka, Tamil Nadu, Punjab, or Nepal. Notably, one farm was managed by a PhD researcher conducting concurrent field research, while another employed a landscape professional who supervised farm operations and labour management.

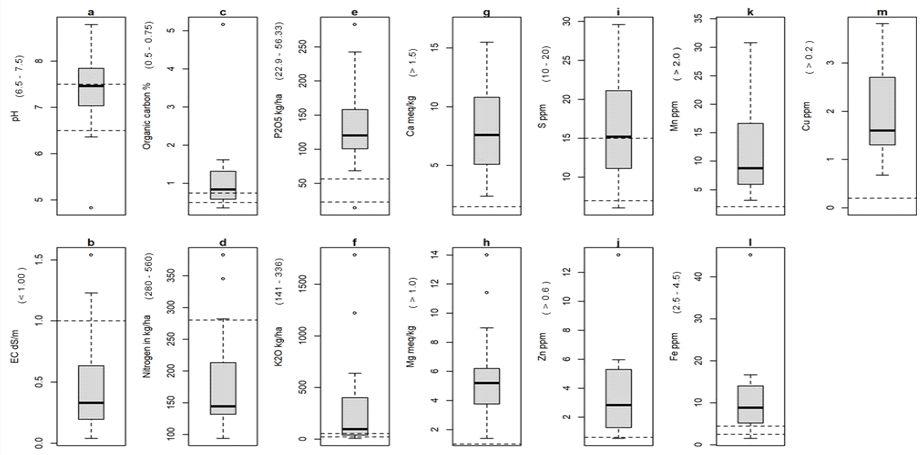
Soil nutrient profiles

Soil nutrient analysis revealed variability in pH, electrical conductivity (EC), soil organic carbon (SOC) and macronutrient (NPK) levels across farms (Fig 2). Most soils exhibited slightly basic pH values within or close to the optimal range, except F14, which was acidic (pH 4.83). EC values were largely within acceptable limits. SOC levels in six farms fell within the recommended range (0.5-0.75%), while nine farms recorded values exceeding 1%, with F9 showing exceptionally high SOC (5.16%), comparable to forest soils and well above the national average of 0.54% for healthy agricultural soils (Das *et al.*, 2022).

Nitrogen levels were generally low, whereas phosphorus was excessive in all farms except F14, which was below acceptable limits. Potassium levels varied widely, with most farms falling below optimal ranges. Micronutrient availability also showed considerable variation, indicating heterogeneous soil conditions and the need for site-specific soil fertility management.

Biodiversity on the farms

All farms exhibited high biodiversity, with consistent presence of birds, butterflies and insect pollinators. Peacocks were commonly observed and farmers reported regular sightings of mongoose, snakes and rodents, indicating intact trophic interactions. Each farm supported approximately 15-30 species of pollinators and beneficial insects, including bees, butterflies, flies and ants. Most farms maintained 5-10 tree species that served as host plants and habitats for avifauna and insects. Trees and flowering plants such as *Helianthus annuus*, *Tagetes erecta* and *Plumeria alba* enhanced pollination and seed dispersal, promoting cross-pollination of crops. These farms functioned as localized biodiversity refugia with distinctly cooler microclimates relative to surrounding landscapes.



Dotted lines indicate the ideal range or threshold values for optimal soil health. Parameters shown include: (a) pH (b) Electrical conductivity (c) Soil organic carbon (d) Nitrogen (e) Phosphorus (f) Potassium (g) Calcium (h) Magnesium (i) Sulphur (j) Zinc (k) Manganese (l) Iron and (m) Copper.

Fig 2: Box plot representation of soil chemical properties across the surveyed farms.

This study examined the diversity of natural farming practices in urban Bengaluru and their associated socio-ecological benefits. Even prior to the adoption of the Sustainable Development Goals (SDGs), farmers in Karnataka had actively engaged in nature-based solutions (NbS) for soil and plant health management (Khadse *et al*., 2018). All 15 surveyed farms practiced at least five biodiversity-friendly agricultural practices, often adapted through local knowledge and experience while maintaining stable productivity.

Key findings included wide variations in soil management practices; nuanced pest control approaches such as the CVR method; farm-specific cover crop selection; layered cropping in F7 and consistently high soil organic carbon (SOC) levels, frequently exceeding the Indian agrarian average of 0.54% (Das *et al*., 2022). Soil and seed harvesting by farms F7 and F13 and increased dependence on digital marketing platforms were also notable.

Companion cropping was widely adopted to enhance soil health and pest regulation. For example, banana cultivation as a companion crop in F4 was associated with improved crop productivity, potentially due to plant growth-promoting rhizobacteria and beneficial endophytes and volatiles reported in banana root systems (Patel *et al*., 2018; Ting *et al*., 2008). Similar benefits from clover, coriander and other companion crops included nitrogen enrichment, pest suppression, pollinator attraction and improved crop quality (Midega *et al*., 2015; Orzech and Zaluski, 2020; Leakey *et al*., 2001; Reddy, 2017). Long-term experimentation at F13 further demonstrated yield and quality gains. Integration of trees enhanced soil microbial activity, nutrient retention, biodiversity and climate resilience (Barrios *et al*., 2018; Dierks *et al*., 2021).

Most farmers sourced seeds from non-organic systems, however, farms F7 and F13 exclusively cultivated indigenous and heirloom varieties and practiced seed saving, supporting genetic diversity, nutritional quality and climate resilience (Kapoor *et al*., 2022; Acevedo *et al*., 2020).

Urban and peri-urban locations enabled farms to leverage online platforms for marketing, although the absence of standardized MSPs for organic produce and limited engagement with Farmer Producer Organizations created pricing challenges (Misra and Singh, 2016). Income diversification through cattle-based livelihoods, value-added products, farm tourism and training programs enhanced economic resilience while increasing public awareness of sustainable agriculture. Biodiversity benefits were evident through frequent bird and butterfly presence. Reduced water use and adoption of rainwater harvesting and soil-water conservation-critical in the context of Bengaluru's growing water stress were notable (Thippiah, 2017; Martin *et al*., 2024).

Overall, many farms fulfilled three or all four NbS framework functions - sustainable production and livelihoods, green infrastructure, ecosystem restoration and conservation, demonstrating viable pathways for climate-resilient, biodiversity-rich urban agriculture (Simelton *et al*., 2021).

CONCLUSION

This research studied 15 nature-friendly urban farms in and around Bengaluru city and found them using a diverse-mix of NbS for farm management and income generation. Some of these farms have developed their own methods of soil, pest and crop management. Their location in the city allows them to engage in new ways of earning through conducting workshops for educational institutions and farm-tourism events *etc*., apart from livelihoods earned from food-crops and dairy products. These farmers use online forums to sell their produce showcasing successful business models that enable several other advantages of providing a healthy habitat for nurturing urban biodiversity, reducing carbon footprint, improving soil health, contributing to climate change mitigation, as well as providing a hands-on platform for educating the future generations on ways to a sustainable living. The study also raises important questions on the need for research on companion crops and banana plantations on soil and plant health, the need for identification of best practices through careful scientific exploration of individual practices, the need for mandating organic certifications to make natural farm produce more acceptable and finally the need for setting suitable pricing for this produce.

ACKNOWLEDGEMENT

The present study was supported by Agence Française de Développement (AFD) through the research project-"Greening Urban Food Systems: Building Sustainable urban agriculture practices in Bengaluru through nature-based solutions".

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

The IIHS Ethics Committee approvals and certifications were received before we proceeded with the farm surveys. Telephonic verbal consent was obtained from the farmers before we undertook the trips and surveys at each of the farms.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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