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SIFS farms as multi-trophic biodiversity refugia across three agroclimatic zones of India

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Abstract

Conventional high-input farming has been associated with substantial biodiversity declines and cascading ecosystem service consequences across agricultural landscapes. Sustainable Integrated Farming Systems (SIFS), combining crops, horticulture, agroforestry, livestock, and aquaculture with minimal external inputs, represent a climate-smart alternative promoted by Welthungerhilfe across India, Nepal, and Bangladesh. Despite growing adoption, multi-trophic evidence for SIFS as biodiversity refugia remains limited.

We assessed whether SIFS enhances multi-trophic biodiversity spanning pollinators, arthropod natural enemies, herbivores, soil macrobiota, non-crop plants, and birds relative to conventional farming across three agroclimatic zones of India, while examining plant–arthropod interaction networks for important species.

We surveyed 45 farms across West Bengal (Sundarbans), Rajasthan (Banswara), and Jharkhand (Deoghar) under Old SIFS, New SIFS, and Conventional management from December 2024 to April 2026. Bees were sampled by transects and pan traps; floral visitation by quadrats; arthropods by vacuum sampling; soil macrobiota by monoliths; and birds by point-count transects. Interaction networks were built from focal observations. Responses were modelled by GLMMs.

Old SIFS farms supported 2.3-fold higher bee abundance ($p < 0.01$) and 49 % higher bee species richness ($p < 0.05$) than Conventional farms. Flower visitation was elevated in New SIFS ($\times 2.1$; $p < 0.05$) and Old SIFS ($\times 2.5$; $p < 0.01$). Spider abundance was 1.9-fold greater in Old SIFS ($p < 0.05$), and predatory soil macrobiota were 3.1-fold more abundant in Old SIFS ($p < 0.05$), extending natural enemy gains below-ground. Bird species richness and guild-specific abundances (granivores, carnivores, nectarivores) were significantly higher in Old SIFS. Additional biodiversity responses were variable and will be discussed in full. Interaction networks revealed pronounced regional structuring in connectance, nestedness, and specialisation. Bee-specific sub-networks identified non-crop plants with high degree and betweenness centrality, acting as generalist connectors and structural bridges within farm-level pollination networks.

SIFS farms function as multi-trophic biodiversity refugia within smallholder landscapes. Ecosystem service recovery was not always uniform along the SIFS transition. These findings provide among the first multi-trophic, cross-regional evidence that SIFS constitutes

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a nature-based solution for biodiversity conservation, climate resilience, and food security in South Asian smallholder landscapes.

Keywords: Agroecology, biodiversity refugia, ecosystem services, interaction networks, multi-trophic, nature-based solutions, SIFS, smallholder farming, South Asia