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Ecological importance of common weeds in agro-ecosystem of Saidabad Block

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Abstract
Traditionally, weeds are considered to be unwanted vegetation in agriculture systems due to their competitive effects on the productivity of the crop. In recent years, however, agroecological research has focused on their key ecological roles and their contribution to ecosystem sustainability. Common weeds of the agroecosystem in Saidabad block were studied with a focus on their functions in the agroecosystem in relation to their ecological significance in terms of soil health, hydrological regulation, conservation of biodiversity, nutrient cycling and ecosystem multifunctionality. Grasses like Echinochloa crus-galli and Cynodon dactylon, broad-leaved weeds like Trianthema monogyna, Commelina benghalensis and Cleome viscosa and sedges like Cyperus and Fimbristylis are common species observed in the agricultural fields of the region. They participate in soil stabilization, addition of organic matter, retention of soil moisture and control of erosion particularly in rain-fed and semi-irrigated agricultural conditions. Weeds are also a source of habitat and food for pollinators, predators, parasitoids, and beneficial soil organisms that help with biological pest control and preserve biodiversity. Furthermore, some weed species carry with them various applications such as fodder, medicinal, ethnobotanical and phytoremediation uses, which are important applications that cannot be overemphasized in the rural agroecosystems. The study also highlights the importance of site-specific and ecological weed management approaches, such as zonal management, integrated weed management, and decreased reliance on herbicides, to help achieve a balance between crop productivity and ecological sustainability. Adaptive weed management of beneficial weed communities can improve the resilience of the ecosystems, climate-smart agriculture and long-term agricultural sustainability in Saidabad block rather than eradication.

Keywords: Agroecosystem, biodiversity, ecosystem multifunctionality, soil health, ecological services, integrated weed management, sustainable agriculture

Introduction

Agricultural landscapes are ‘living landscapes' in which crops are co-existing with a diversity of associated plants, including weeds. Weeds are plants growing in locations where they are not wanted; traditionally they are recognized for their ability to compete with cultivated plants for 'light, water, nutrients, and space,' which lowers crop productivity and makes crop management more difficult and expensive. In the past, chemical control of weeds, tillage, and cultivation have been the major methods used in conventional agriculture. In recent years, however, agroecology and ecosystem science have revolutionized the definition of weed as a negative element of the farming system, offering new insights into how weeds can be useful. New developments in agroecology and ecosystem science have, however, challenged the conception of weeds as purely deleterious elements of farming systems, and provided new insights into the potential usefulness of weeds. There is growing evidence that many weed species are important in their ecological functions such as providing ecosystem resilience, biological pest control, support for pollinators, nutrient cycling, biodiversity conservation and soil health. Weeds are therefore not only viewed as competitors, but are also gaining in importance as a functional component of agroecosystems that can offer valuable ecosystem services if managed properly. In agroecosystems weeds are generally classified into agrestals and ruderals (Moreau *et al*., 2024) [5]. Agrestals are species that are very closely linked to cultivated fields and crop cycles while ruderals are well suited to disturbed sites like field margins, roadsides, bunds, and fallow fields. They play a crucial role in the vegetation diversity and ecological stability of mixed and low-input farming systems. Vegetative weeds found within agricultural fields generally are comprised of grasses, broad-leaved weeds and sedges which are very well suited to local climatic and soil conditions. The commonly found weeds in Indian agroecosystems are *Eleocharis* and *Cyperus spp*. and grasses such as *Echinochloa crus-galli* and *Cynodon dactylon*, broad-leaved weeds like *Trianthema monogyna*, *Commelina benghalensis*, *Celosia argentea* and *Cleome viscosa* and sedges like *Cyperus spp.* and *Fimbristylis spp*. While considered undesirable vegetation, these plants are an indispensable component of agroecosystem biodiversity and play various roles in ecosystem processes in cultivated landscapes (One Earth Network, 2025) [6].

The agroecosystems of northern India are mosaic systems with different weed communities arising from mixed cropping, seasonal cropping, and field-margin vegetation and management intensity. The agricultural systems in the area are mostly kharif and rabi crops grown in rain-fed and semi-irrigated fields, thus providing heterogeneous habitats to support various weed communities. In these systems weed communities may have great influence on the functioning of the system at several levels. Dense weed vegetation stabilizes soil, decreases erosion, helps to form soil structure, and increases water infiltration, especially during the rainy season (monsoon) when bare ground is prone to run-off and nutrient loss. Root systems of perennial grasses and sedges hold soil particles and keep soil porous, and breakdown weed biomass adds organic matter and enhances soil nutrient cycling (Salomé *et al*., 2020) [2]. Also, weed residues can sequester carbon for the long-term and provide a source of carbon for microbial activity and thus

long-term soil fertility and sustainability. Weeds also have many beneficial effects on soil processes, and they are also significant sources of habitat and food for many organisms in agroecosystems. Flowering weeds provide nectar and pollen for pollinators (bees, butterflies and hoverflies) as well as providing food for herbivorous insects and their natural enemies. Biological control of crop pests by diverse communities of predators and parasitoids, such as spiders, ground beetles, ladybird beetles, lacewings, and parasitic wasps is enhanced. In arable farming systems, research indicates that higher diversity of weeds may be associated with increased multifunctionality of farming systems, such as better pest control, pollination, and nutrient-use efficiency. Weed vegetation can also provide supporting soil organisms such as microbial communities, earthworms and nematodes involved in decomposition and nutrient transformation processes. Weeds thus contribute to the ecological balance and enhance the environmental stability of agricultural systems. Agroecological research in recent years has focused on the multiple functions of ecosystems, which would provide various ecosystem services simultaneously, including soil fertility maintenance, conservation of biodiversity, carbon sequestration, pollination and pest control. Agricultural systems with a high weed fraction tend to be more multifunctional than systems that are farmed without weeds, particularly in less intensive systems. This has resulted in the emergence of ideas like "service weeds," which are naturally occurring weed species that offer ecological services without causing excessive competition to the crop (Moreau *et al*., 2024) [1]. This is not an opinion about letting weeds run wild, but it is an opinion on the management of weeds in an ecologically sound way that will maintain productivity of the crop and function of the ecosystem. Methods like zonal weed management, retaining vegetation at the edges of fields, decreasing reliance on herbicides, crop rotation, and integrated weed management can help maintain beneficial weed functions without significant reduction in crop production. Apart from ecological roles, many common weeds have also economic, medicinal and ethnobotanical value, in rural agricultural community. Some of the grasses are used for fodder crops and most of the broad-leaved weeds for traditional use in medicine in the local health care systems. The species like *Trianthema monogyna, Commelina benghalensis* and *Cleome viscosa* are employed in traditional medicine and can also play a role in the phytoremediation and soil conditioning processes in disturbed areas. At the regional level, in areas such as Saidabad where agricultural activities are interrelated with livestock farming and traditional farming methods, the use of these multifunctional weed species can play an important role in sustainable use of resources (Moreau *et al*., 2024) [1]. Weeds, in spite of the fact of their ecological role, can also serve as alternate hosts for crop pathogens, insect pests and mites when managed poorly. Weed growth can become out of hand, which can increase competition with crops and decrease productivity. It is, therefore, important to understand the balance between beneficial and harmful effects of weed communities to develop sustainable weed-management strategies. Ecological weed management focuses on the regulation of weeds and does not aim for complete eradication, rather beneficial species of weeds can be maintained in non-crop areas (bunds, fallows, field margins etc.) and problematic weeds are taken out of the crop areas (Climate-Smart Weed Management for Global Food Security, 2024) [9]. These approaches are in line with the principles of agroecology, biodiversity protection, and climate-smart agriculture. Hence, the study of the role of common weeds in agroecosystem of Saidabad block is necessary to understand the contribution of common weeds towards soil health, hydrological regulation, maintenance of biodiversity, multifunctionality of the agroecosystem and sustainable agricultural productivity. In the current study, ecological functions of common weed species in the agricultural ecosystems of Saidabad were assessed, and the potential of adaptive weed management for long-term sustainable agricultural ecosystems and production was evaluated (Garcia *et al*., 2024) [3].

Weeds as part of agro ecosystems

Weeds are unwanted plants that grow in an undesirable location, especially in arable land, fallow land, bunds and field margins. They tend to be divided into two groups in agroecosystems: agrestals or species that are tightly linked to crop fields and ruderals, or species that thrive in disturbed environments like roadsides and field margins. The common weeds observed in the kharif and rabi seasons in the Saidabad-type agro landscape are grasses like *Echinochloa crus-galli* and *Cynodon dactylon*, broad-leaved plants like *Trianthema monogyna, Celosia argentea, Commelina benghalensis* and *Cleome viscosa*, sedges like *Cyperus difformis* and *Fimbristylis miliacea*. Rice, mustard, and other crops are commonly affected by these species, but survey results in field survey across agricultural districts in North India suggest that these species play an important role in the diversity of the plants in crop canopies, which in turn has an impact on the nutrient cycling, microclimatic conditions, and diversity of the invertebrates in the crop systems (Salomé *et al*., 2020) [2].

Ecological functions of common weeds

1. Soil health enhancement and erosion prevention

In agroecosystems, weeds can play a critical role in soil health in areas where farmers do not practice cover cropping and choose bare soil tillage, like in Saidabad. Weeds grow rapidly and can generate considerable biomass that, when cut, or partially incorporated into the soil, can increase organic matter levels and the cycling of nutrients. These plants add nutrients like nitrogen, phosphorus and potassium to the soil, and various grasses and broad-leaved weeds uptake and hold nitrogen, thereby reducing the leaching of nitrogen. Also, residues of the roots and shoots add carbon to the soil and enhance soil fertility. Weed species also contribute to soil structure and soil erosion control. Agricultural fields that were recently tilled or sloped have dense root systems of species like *Cynodon dactylon*, *Echinochloa crus-galli* and *Cyperus* species which bind soil particles, reduce surface runoff and minimize soil erosion. The function of this is as important as in Saidabad-type rainfed or semi-irrigated systems where heavy rainfall can wash away exposed topsoil quickly when crop cover is low (Garcia *et al*., 2024) [3].

2. Water related functions

Equally, in monsoon climates with a summer dominated period weeds can have a significant effect on hydrological processes in agroecosystems. They prevent the raindrops from reaching the soil's surface and thus lessen the direct effects of rain on the soil surface, decrease soil crusting, and preserve soil porosity. The ability of dense weed cover

between crop rows or along the crop bundles to improve water infiltration and to reduce surface evaporation can also indirectly benefit the water-use efficiency of the crop. In these situations, weed strips or short-term fallow crops can serve as a green mulch and/or protective buffer over plant canopy, especially in fields with low organic matter content where conserving soil moisture is critical for maintaining crop productivity (Indian Society of Weed Science [ISWS], 2023) [4].

3. The diversity of species and their interactions within a trophic system

Weeds are not only a competitor to crop plants, they also serve as a haven for various organisms that are vital for agroecosystem function and stability. In many agricultural landscapes in the North of India, even patches of weeds at low densities within and around crop fields can provide v aluable habitats and food for pollinators (including bees, hoverflies and butterflies) and herbivorous insects and their natural enemies. Weed diversity in arable fields, especially in intensive cereal based cropping systems has been strongly correlated with higher populations of predators and parasitoids such as spiders, ground beetles and hemipteran predators which also help to regulate crop pests, including aphids (Climate-Smart Weed Management for Global Food Security, 2024) [9]. Weed vegetation also promotes soil biological activity in the surface layer of the soil, for example, by providing habitat for beneficial nematodes and other soil fauna that promote nutrient cycling and ecosystem productivity.

Weed-rich fallows and bund vegetation could thus serve as valuable reservoirs of biodiversity in the Saidabad block where most cropping systems are mixed and field-margin vegetation is maintained, and could help to increase ecological resilience and support multiple ecosystem functions (Rahman *et al*., 2024) [5].

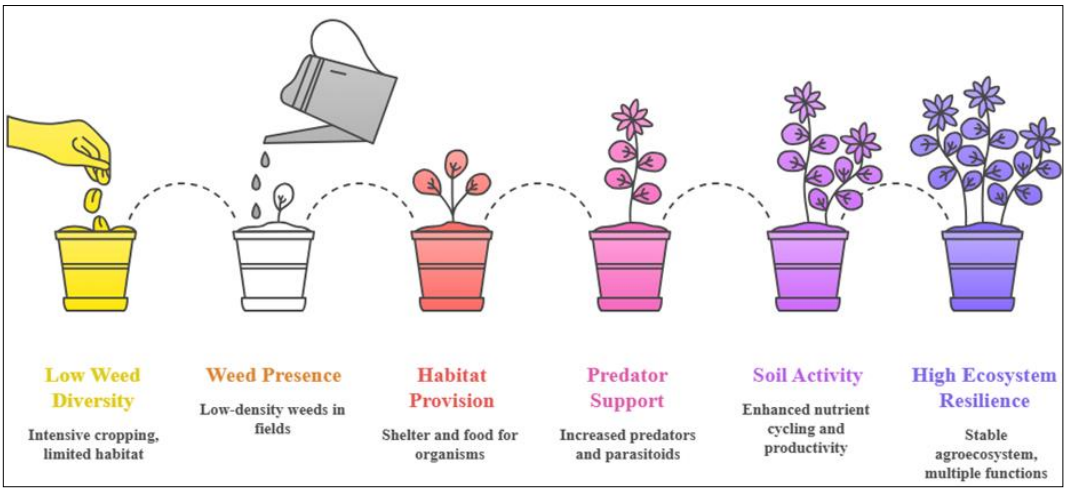

Fig 1: Weed Diversity to Ecosystem Resilience

Potential effects of weeds on pests and diseases

Considering the species composition of weeds, and the level of management applied, weed species can either act as a source of pest and pathogen or also be a vital component of biological control. Some weeds may be alternate hosts for crop pathogens, insect pests and mites, and can exacerbate the pest problem if not controlled. Several pathogens and insect pests of rapeseed–mustard agroecosystems have been reported on broad-leaved weeds like Chenopodium and species of Melilotus in India. In contrast, a variety of weed communities also provide nectar, pollen, and shelter resources for beneficial insects such as ladybird beetles, lacewings, parasitic wasps and spiders, which then spread to nearby crop fields and help reduce the levels of aphids, caterpillars and other agricultural pests. So, in the agroecological setting of Saidabad, keeping the weed burden moderately and strategically on field margins, bunds and fallow patches could thus help in controlling pests' natural enemies instead of creating more pest problems, especially in conjunction with a decreased use of broad-spectrum pesticides (Indian Society of Weed Science [ISWS], 2023) [4]. The concept of ecosystem multifunctionality is becoming more prominent in recent agroecological research, being the simultaneous provisioning of multiple ecosystem services including soil fertility maintenance, pest regulation, pollination support, nutrient cycling and carbon sequestration. European studies on agriculture based on cereal crops have shown that fields with more weeds tend to have higher multi-functionality scores, especially if weed diversity is preserved in less intensive crop management. Weed diversity helps to optimize nutrient use efficiency in crops, soil health and functional capacity and carbon sequestration, and promotes biodiversity and wildlife. In agroecosystems typical of Saidabad, where low inputs and mixed cropping is common, the weed community can also act as an ecosystem engineer, enhancing the ecological resilience and multifunctionality of agroecosystems albeit when managed adaptively and not supposed to be eliminated entirely (One Earth Network, 2025) [6].

Potential for weed use outside of "pests"

Some of the common weeds in Indian agroecosystems have utilitarian value besides their ecological services, which is very significant for the sustainable farm management and rural livelihoods. The grasses like *C. dactylon* and some leguminous weed species are widely used for fodders for livestock, especially in rainfed and marginal agricultural lands, as grazing or cut-and-carry fodder. Numerous plants that have traditionally been considered weeds are also known for their medicinal and ethnobotanical properties. Several Indian traditional medicinal and veterinary uses of local species like *Trianthema monogyna*, *Commelina benghalensis* and *Cleome viscosa* have been recorded. Some weed species are also heavy metal and nutrient tolerant, which stabilizes soil, facilitates nutrient absorption and

phytoremediation in degraded or polluted agricultural patches. These multifunctional weed species can thus be considered as additional forage resources or as buffer vegetation in agroecosystems like Saidabad where the livelihoods rely on the cultivation of crops and livestock. Finally, the implications for management in the Saidabad block were identified (Tamil Nadu Agricultural University [TNAU], 2024) [7].

Weeds are recognized as providing ecological values, but uncontrolled growth of weeds will cause significant yield loss of crops and high management costs. Rather, it emphasizes the importance of site-specific and eco-sensitive approaches to weed management for the agroecosystem of Saidabad. A zonal management strategy is one effective solution, which allows weed cover to be allowed or encouraged around field boundaries, along bunds and in fallow areas and weeds are controlled within the crop rows to optimize crop productivity and weed benefits. In addition, agroecological management may encourage the establishment of desirable "service weeds" such as non-invasive grasses, leguminous herbs, and nectar-rich forbs that enhance soil fertility, pollinator and biological control. These species can be deliberately considered as a part of the farming environment and used as functional part of agroecosystems instead of being regarded as weeds.

In addition, limiting reliance on broad-spectrum herbicides by implementing mechanical, cultural and biological weed-management strategies, such as timed tillage, crop rotation and whenever possible, cover cropping, can reduce the effects of herbicides on beneficial flora and fauna. These strategies, when coordinated, can facilitate the shift from eradication-oriented weed management in Saidabad type agricultural systems to an ecosystem-based weed management, which can contribute to the general principles of agroecology and climate smart agriculture (Integrated Weed Management – A Sustainable Approach for Indian Agriculture, 2025) [8].

Characteristic	Weed-Rich Fields	Diverse Weed Floras	Saidabad Agro-Ecosystems	Fodder and Livestock Feed	Medicinal and Traditional Uses	Soil Conditioning and Phytoremediation
Multifunctionality Score	Higher	Contributes to nutrient use efficiency	Ecosystem engineers	Used as grazing or cut-and-carry fodder	Documented medicinal or ethno-botanical uses	Tolerance to heavy metals
Management	Not excessively intensive	Supports biodiversity and wildlife	Managed adaptively rather than eliminated	Integrated into farm-management plans	Integrated into farm-management plans	Contributes to nutrient uptake
Examples	Cereal-dominated landscapes in Europe	Diverse weed floras	Saidabad-type agro-ecosystems	Cynodon dactylon, leguminous weeds	Trianthema monogyna, Commelina benghalensis, Cleome viscosa	Weeds tolerant to heavy metals

Fig 2: Weed Multifunctionality and uses

Conclusion

Common weeds of the agro-ecosystem of Saidabad block are not only a problem associated with the crop production but also play a significant role in determining soil fertility, water regime, biodiversity and the regulation process of pests. The empirical evidence from North Indian agro landscapes reveals that a significant number of weed species play a role in nutrient cycling, erosion control, beneficial insects and soil fauna, thus promoting the multifunctionality and resilience of the ecosystems. However, attention must be paid to their management to avoid diseases and pests that deplete yields (competition) and to reduce their importance as alternate hosts. Using the ecological value of common weed species, farmers and planners in Saidabad can use a zonal approach to weed management with low input strategies to take advantage of the positive ecological role of common weed species for more sustainable and resilient agriculture.

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