BACKYARD FARMING PRODUCTION FOR MAXIMUM UTILIZATION OF AVAILABLE NATURAL RESOURCES WITH ROTATIONAL MIXED CROPPING TECHNIQUES

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Abstract: Rightful utilization of natural resources for more and more production within the frame of basic principles of sustainable development, the only source of endless wealth on this erath forever, that compulsive to adop and practice as act of humanity for humankind. Green accounting, the key of transparency to virtuous utilisation of the natural resources management, add up a rationale as an indices illustrating the methodologies of sustainable development approaching to evergreen perennial leafy herbal spice of indigenous *Allium odorum* crop as leading component in the rotational mixed cropping techniques of backyard farming through maximum utilization of available natural resources which surrounds our environment. The estimated multiple cropping Index (MCI) based on the crop production system with mixed cropping pattern of vegetables production in the Backyard farming for value addition to dietary, strengthening to economic level and to increase high efficiency to environment sustainability. The indepth investigation work to environmental resources sustainability reflect Anushka 493 F1 (Sponge gourd) (11-15 t/ha), Palee F1 (Bitter Gourd) (8-9 t/ha), Samrat (Cucumber) (9-10 t/ha), Reenu (Bean) (5-7 t/ha) in January-February to June (Zaid season); Indica Hybrid Seed (Chilli) (0.4-0.6 t/ha), Basanti (Okra) (8-10 t/ha), Brinjal (15-25 t/ha), Kuroda Improved (Carrot) (25-35 t/ha), in June-July to September-October (Kharif Season); Green Hero (Cabbage) (20-25 t/ha), Shriram Mariko (Cauliflower) (15-20 t/ha), Green Magic (Broccoli) (15-20 t/ha), Pea (2-3 t/ha), Ruby Queen (Beet roort) (15-20 t/ha), Palak Seed All Green (Palak) (10-12 t/ha) in October- November to December-January (Rabi season) and an additional yield of *Allium odorum* of 12-14 t/ha/harvest was add together to the green accounting of natural resources utilization. The computed multiple cropping index (MCI) with a value of 300% well deserved and exonerated the accountability of green accounting for sustainable development as against aggregated indicators of resource depletion i.e. expose land unused without covering by green by human on earth for human yet to come.

***Key words*:** Natural resource management, green accounting, sustainable development, Multiple Cropping Index, Backyard farming, mixed rotational cropping.

I. INTRODUCTION

In the face of rapid global population growth, declining arable land per capita, and increasing pressure on food security, intensification and diversification of agricultural production systems have become imperative (Tilman et al., 2011). Backyard farming—defined as small-scale agricultural production carried out in the homestead precincts or peri-urban spaces—has emerged as a sustainable strategy to optimize land use and improve household nutritional security (Fantini, A. 2023). Backyard farms harness available natural resources such as sunlight, soil moisture, organic wastes, and biodiversity to generate vegetables, fruits, legumes, and medicinal plants, and oftentimes integrate livestock for comprehensive resource cycling (Chakraborty & Basu, D. 2018; FAO, 2017).

Backyard farming is increasingly recognized not only for its contribution to food and nutrition security but also for ecological resilience and income generation among rural and urban households (Galhena et al., 2013). In many developing regions, backyard systems serve as safety nets that buffer against external market fluctuations and crop failures. These systems capitalize on the synergy between plant and animal components, organic inputs, water conservation structures, and agro-biodiversity to maximize productivity per unit area.

To further enhance the efficiency of backyard systems, rotational mixed cropping emerges as a key agronomic intervention. Rotational mixed cropping involves the deliberate sequencing and combination of multiple crop species across time (rotations) and space (mixed stands) to improve soil fertility, disrupt pest and disease cycles, and optimize the use of natural resources (Liebman & Dyck, 1993). Historically, traditional agricultural systems worldwide have employed mixed cropping and rotation as adaptive strategies to maintain long-term productivity and ecological balance (Altieri, 1999).

Rotational mixed cropping is distinguished from monoculture by its ability to utilize diverse crops with complementary growth cycles, root architectures, and nutrient requirements (Vandermeer, 1992). Such diversification enhances resource partitioning—whereby distinct crops access different soil depths for water and nutrients—reducing competition and increasing total system yield (Dordas et al., 2012). Additionally, the incorporation of legumes in rotation sequences adds biological nitrogen to the soil via symbiotic fixation, decreasing the need for external nitrogenous inputs and enhancing sustainability (Peoples et al., 2009).

In backyard settings, integrating rotational mixed cropping techniques can contribute to efficient utilization of light, water, and nutrient resources throughout the year (Malézieux et al., 2009). For instance, fast-growing leafy vegetables can be intercropped with slower-maturing fruit crops, while root vegetables may follow cereal residues to exploit residual moisture and nutrients (Davis et al., 2012). This temporal and spatial diversification helps to minimize soil erosion, maintain continuous ground cover, and enhance carbon sequestration (Drinkwater et al., 1998).

The synergistic benefits of rotational mixed cropping are manifold: improved biodiversity, enhanced pest and weed suppression through allelopathy and habitat disruption, balanced nutrient cycling, and increased overall farm productivity per unit area (Gliessman, 2015). From a socio-economic perspective, producing multi-purpose crops can stabilize household incomes by reducing dependency on single-market commodities and offering surplus produce for sale or barter (Abebe 2016).

By integrating backyard farming with rotational mixed cropping, resource-poor farmers gain opportunities to maximize available natural inputs—sunlight, rainwater, organic residues, and family labor—without heavy reliance on purchased fertilizers or pesticides (Pretty, 2008). Such systems align closely with principles of ecological intensification, which aim to increase agricultural output while conserving environmental quality (Bommarco et al., 2013).

Extensive research has demonstrated that diversified cropping systems improve yield stability under climatic variability. For example, mixed cropping systems have shown greater resilience to drought and pest outbreaks compared to monocultures (Finckh & Wolfe 2006). In backyard systems, this resilience translates into secure year-round food supplies and reduced vulnerability for household nutrition (Gaudin et al., 2015).

Although the benefits are well-recognized, adoption of rotational mixed cropping within backyard farms remains uneven due to socio-cultural practices, limited technical knowledge, and constraints in access to quality planting materials (Mortensen & Smith 2020). Addressing these challenges requires context-specific extension services, participatory training, and demonstration plots that exemplify the principles and benefits of diversified cropping in small spaces (Kumar & Nair, 2004).

This introduction establishes the basis for examining the strategic significance of home farming combined with rotational mixed cropping as a means to achieve sustainable food systems, environmental stewardship, and improved livelihoods. The subsequent sections will examine particular implementation methodologies, resource optimization methods, and case studies where integrated systems have markedly enhanced production and environmental results.

II. METHODOLOGY

Study Area and Experimental Site

The study was conducted during the agricultural years 2023–24 and 2024–25 under a backyard farming system aimed at maximizing the utilization of available natural resources through rotational mixed cropping techniques. The experimental site was within a household homestead area characterized by limited land availability at Kakching Wairi (24.51^{0}N latitude and 93.97^{0}E longitude), Kakching district, Manipur, representing a typical smallholder backyard farming systems. The soil of the site was well-drained, moderately fertile, and managed organically using farmyard manure, compost, and crop residues without the application of synthetic fertilizers or chemical pesticides.

The region experiences a subtropical climate with three distinct cropping seasons—Zaid, Kharif, and Rabi—which were utilized for year-round production through crop rotation and diversification.

Experimental Design and Cropping Strategy

The methodology followed a season-wise rotational mixed cropping system, integrating vegetable crops with the perennial spice-cum-herbal crop *Allium odorum*. The experimental layout was designed to ensure optimal use of sunlight, soil moisture, and nutrients while maintaining continuous ground cover throughout the year.

The cropping system involved:

- Triple mixed cropping during the Zaid season
- Diversified mixed cropping during Kharif and Rabi seasons
- Continuous integration of *Allium odorum* as a perennial intercrop across all seasons

Crop selection was based on growth habit, rooting depth, duration, and compatibility to minimize competition and enhance complementarity among component crops.

Crop Management Practices

All crops were cultivated under organic management practices. Land preparation involved light tillage and bed formation suitable for mixed cropping. Organic inputs such as vermicompost and decomposed farmyard manure were applied uniformly before sowing. Mulching using crop residues was practiced to conserve soil moisture and suppress weeds.

Irrigation was provided using household water sources as per crop requirements. Manual weeding and biological pest management practices were adopted. Harvesting was done at physiological maturity, and yields were recorded season-wise.

Seasonal Crop Rotation and Yield Recording

Crop rotation was implemented across Zaid, Kharif, and Rabi seasons to improve soil health, break pest and disease cycles, and ensure year-round productivity. Yield data were recorded on a **tonnes per hectare (t/ha) basis** under organic conditions.

Table I. Vegetable crop production along with perennial spice-herbal *Allium odorum* with cropping season (2023–24 and 2024–25)

Sl. No.	Crop Season	Name of Crops	Yield (t/ha) (Organic)	Remark
1	Zaid (January–February to June)	Anushka 493 F1 (Sponge gourd)	11–15	Mixed triple cropping. Rotational systems with perennial add additional yield and income

Sl. No.	Crop Season	Name of Crops	Yield (t/ha) (Organic)	Remark
		Palee F1 (Bitter gourd)	8–9	
		Samrat (Cucumber)	9–10	
		Reenu (Bean)	5–7	
		Allium odorum	12.4 per cutting	
2	Kharif (June–July to September–October)	Indica Hybrid Seed (Chilli)	0.4–0.6	
		Basanti (Okra)	8–10	
		Brinjal	15–25	
		Kuroda Improved (Carrot)	25–35	
		Allium odorum	11.4 per cutting	
3	Rabi (October–November to December–January)	Green Hero (Cabbage)	20–25	
		Shriram Mariko (Cauliflower)	15–20	
		Green Magic (Broccoli)	15–20	
		Pea	2–3	
		Ruby Queen (Beetroot)	15–20	
		Palak Seed All Green (Palak)	10–12	
		Allium odorum	14.8 per cutting	

Evaluation of Cropping System Efficiency

To assess land-use efficiency and productivity intensity, the Multiple Cropping Index (MCI) was calculated following the method proposed by Dalrymple (1971) as cited in Reddy (2022). The index was used to quantify the extent of cropping intensity achieved through triple cropping combined with a perennial component.

The formula used was:

Multiple Cropping Index (MCI)= (∑Area planted to different crops in a year/Total cultivated area) ×100

Table II. Multiple Cropping Index following Dalrymple (1971) (cited in Kumar et al., 2024)

Sl. No.	Cropping System	Multiple Cropping Index	Remark
1	Triple cropping mixed with perennial *Allium odorum*	300	Evaluation of cropping system for land-use efficiency very high

Data Analysis

The yield performance of individual crops and integrated systems was evaluated descriptively to assess productivity trends across seasons. The impact of the perennial crop (Allium odorum) was evaluated for supplementary yield, cropping continuity, and revenue stability. The elevated Multiple Cropping Index value served as a metric for effective land utilization and system sustainability.

III. RESULTD AND DISCUSSION

Vegetable Crop Productivity under Rotational Mixed Cropping System

The results presented in Table I clearly demonstrate that the integration of seasonal vegetable crops with the perennial spice-herbal crop *Allium odorum* under a backyard farming system resulted in high productivity across all three cropping seasons (Zaid, Kharif, and Rabi) during 2023–24 and 2024–25. The system effectively utilized available natural resources such as land, sunlight, soil moisture, and organic nutrients through rotational mixed cropping.

Zaid Season Crop Performance

During the Zaid season, mixed triple cropping involving sponge gourd, bitter gourd, cucumber, and bean recorded appreciable yields. Sponge gourd (*Anushka 493 F1*) produced 11–15 t/ha, followed by cucumber (9–10 t/ha), bitter gourd (8–9 t/ha), and bean (5–7 t/ha). These results indicate effective complementary interactions among crops with different growth habits and nutrient requirements.

The perennial crop *Allium odorum* yielded 12.4 t/ha per cutting, contributing additional produce without competing significantly with seasonal vegetables. The higher productivity observed in the Zaid season can be attributed to efficient utilization of solar radiation, improved soil organic matter, and reduced pest pressure due to crop diversity. Similar yield advantages of mixed cropping systems have been reported by Liebman and Dyck (1993) and Malézieux et al. (2009).

Kharif Season Crop Performance

In the Kharif season, diversified mixed cropping recorded variable but satisfactory yields. Chilli (*Indica Hybrid*) yielded 0.4–0.6 t/ha, while okra produced 8–10 t/ha and brinjal recorded 15–25 t/ha. Notably, carrot (*Kuroda Improved*) exhibited the highest yield (25–35 t/ha) among all crops in this season, indicating efficient root zone utilization and residual nutrient availability from the previous Zaid crops.

Allium odorum continued to produce 11.4 t/ha per cutting, confirming its adaptability and productivity across seasons. The sustained yield of the perennial component highlights its role in stabilizing system productivity and income. These findings are consistent with observations made in diversified backyard and home garden systems by Kumar and Nair (2004) and Galhena et al. (2013).

Rabi Season Crop Performance

The Rabi season showed the highest overall productivity due to favorable climatic conditions and cumulative soil fertility improvements. Cabbage yielded 20–25 t/ha, cauliflower 15–20 t/ha, broccoli 15–20 t/ha, and beetroot 15–20 t/ha. Leafy vegetables such as palak recorded 10–12 t/ha, while pea yielded 2–3 t/ha.

The perennial *Allium odorum* recorded its highest yield (14.8 t/ha per cutting) during Rabi season, indicating better growth under cooler temperatures and improved soil conditions. The inclusion of leafy vegetables and legumes further enhanced nutrient cycling and soil health. Similar seasonal yield enhancement in diversified systems has been reported by Drinkwater et al. (1998) and Pretty (2008).

Contribution of Perennial *Allium odorum* to System Productivity

Across all seasons, *Allium odorum* consistently contributed substantial yields without requiring separate land allocation. Its perennial nature ensured continuous harvests, improved land-use efficiency, and provided an additional and stable source of income. The crop also acted as a biological barrier, reducing weed growth and enhancing microclimatic conditions within the cropping system.

The results support earlier findings that integration of perennial components in small-scale farming improves productivity stability and ecological sustainability (Altieri, 1999; Gliessman, 2018).

Evaluation of Cropping System Efficiency

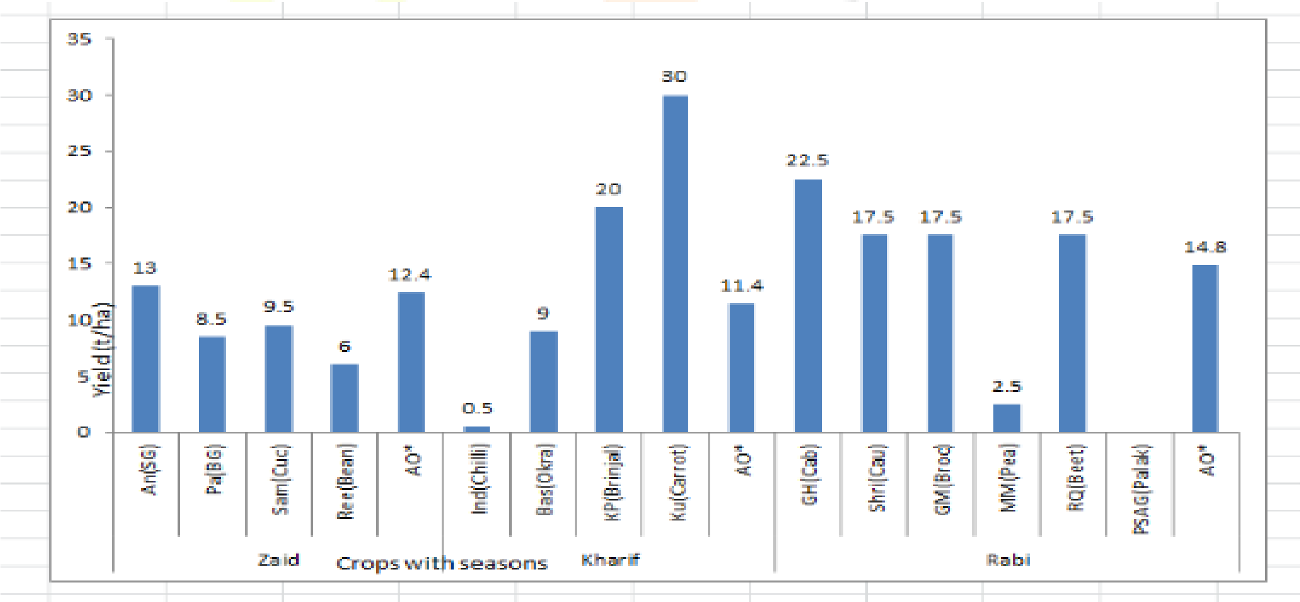
The Multiple Cropping Index (MCI) calculated for the system (Table II) was 300, indicating that the land was effectively cropped three times in a year with additional perennial production. According to Dalrymple (1971), an MCI value above 200 reflects intensive land use, while a value of 300 denotes very high land-use efficiency.

Table II Interpretation

The triple cropping system integrated with perennial *Allium odorum* achieved:

- Maximum utilization of limited backyard land
- Continuous crop cover throughout the year
- Reduced fallow periods
- Enhanced cropping intensity and productivity

These findings corroborate the results reported by Reddy (2022) and Bommarco et al. (2013), who emphasized that diversified cropping systems significantly improve land-use efficiency and sustainability.



Note: An (SG)=Anushka 493 F1 (Sponge gourd), Pa (BG)= Palee F1 (Bitter Gourd), Sam (Cuc)= Samrat (Cucumber), Ree (bean)= Reenu (Bean), Ind (Chilli) = Indica Hybrid Seed (Chilli), Bas (Okra) = Basanti (Okra), KP (Brinjal) = Brinjal (Khamen Pramashika), Ku (Carrot) = Kuroda Improved (Carrot), GH (Cab) = Green Hero (Cabbage), Shri (Cau) = Shriram Mariko (Cauliflower), GM (Broc) = Green Magic (Broccoli), MM (Pea) = Makhayat mubi (Pea), RQ (Beet) = Ruby Queen (Beet root), PSAG (Palak) = Palak Seed All Green (Palak)

Fig. 1. Showing yield (ton/ha) of vegetable crops in three crop seasons viz. Zaid, Kharif, and Rabi in the backyard farming (mean of 2023-24and 2024-25).

Figure 1 presents the mean yield (t ha⁻¹) of different vegetable crops grown under a backyard farming system across three crop seasons—Zaid, Kharif, and Rabi—during 2023–24 and 2024–25. The results reveal marked seasonal and crop-wise variations in yield, highlighting the role of climatic conditions, crop adaptability, and season-specific growth requirements.

Zaid Season

During the Zaid season, overall yields were relatively lower compared to the Kharif and Rabi seasons. Among the crops evaluated, *Anushka 493 F1 (sponge gourd)* recorded the highest yield (13.0 t ha^{-1}), followed by *Basanti (okra)* with 12.4 t ha^{-1}. Moderate yields were observed in *Samrat (cucumber)* (9.5 t ha^{-1}) and *Palee F1 (bitter gourd)* (8.5 t ha^{-1}), while *Reenu (bean)* produced the lowest yield (6.0 t ha^{-1}). *Indica hybrid chilli* showed extremely poor performance with a yield of only 0.5 t ha^{-1}.

The lower productivity during the Zaid season can be attributed to high temperature stress, limited soil moisture availability, and increased evapotranspiration losses, which adversely affect flowering and fruit set (La Pena & Hughes, 2007; FAO, 2017). Heat-sensitive crops such as chilli are particularly vulnerable to pollen sterility and flower drop under summer conditions, resulting in poor yields. However, cucurbit crops like sponge gourd and bitter gourd exhibited better adaptability to Zaid conditions, as reported earlier by Jamal et al. (2022).

Kharif Season

The Kharif season recorded the highest overall yields among the three seasons. *Kuroda Improved (carrot)* achieved the maximum yield (30.0 t ha^{-1}), followed by *Green Hero (cabbage)* (22.5 t ha^{-1}) and *Khamesh Pramashika (brinjal)* (20.0 t ha^{-1}). *A0 (chilli)* yielded 11.4 t ha^{-1}, while *Basanti (okra)* recorded a yield of 9.0 t ha^{-1}.

The superior performance of crops during the Kharif season is mainly due to favourable monsoonal conditions, including adequate rainfall, moderate temperatures, and enhanced soil moisture availability, which promote nutrient mineralization and uptake (Nawaz et al., 2021; Bhattacharyya et al., 2015). Root and cole crops such as carrot and cabbage respond positively to these conditions, resulting in higher biomass accumulation and yield (Guo et al., 2024). The high yield of carrots observed in this study confirms the suitability of backyard farming systems for high-value vegetables under appropriate seasonal management (Altieri, 2018).

Rabi Season

During the Rabi season, cole crops and leafy vegetables performed consistently well. *Shriram Mariko (cauliflower)*, *Green Magic (broccoli)*, and *Ruby Queen (beetroot)* each recorded yields of 17.5 t ha^{-1}, while *Palak Seed All Green (palak)* yielded 14.8 t ha^{-1}. In contrast, *Makhyat Mubi (pea)* recorded the lowest yield (2.5 t ha^{-1}).

The favourable yields of Rabi crops can be attributed to cooler temperatures, reduced pest pressure, and efficient utilization of residual soil moisture, which are conducive to cole crops and leafy vegetables (Pretty et al., 2018; Thies & Grossman, 2023). Similar yield trends for winter vegetables have been reported under small-scale and organic farming systems (Ceglie et al., 2016).

Overall, the results indicate that seasonal variation significantly influences vegetable crop productivity under backyard farming systems, with the Kharif season showing the highest yield potential, followed by Rabi and Zaid seasons. The findings emphasize the importance of season-wise crop planning and diversification to maximize productivity, enhance household nutritional security, and promote sustainable farming practices (Rob et al., 2017; Altieri, 2018). Backyard farming, when integrated with suitable crop selection and appropriate seasonal management, can serve as an effective strategy for sustainable food production in smallholder

The results clearly indicate that rotational mixed cropping combined with a perennial component is a highly efficient strategy for backyard farming systems. The approach enhanced yield stability, diversified production, and optimized the use of natural resources. Crop diversification reduced the risks associated with monocropping and ensured year-round availability of vegetables and herbs for household consumption and income generation.

The high Multiple Cropping Index further confirms that backyard farming, when scientifically planned, can contribute significantly to food and nutritional security, especially for small and marginal farmers. These results align with the principles of sustainable and ecological intensification as suggested by Tilman et al. (2011) and FAO (2017). The findings emphasize the importance of season-wise crop planning and diversification to maximize productivity, enhance household nutritional security, and promote sustainable farming practices (Rob et al., 2017; Altieri, 2018).

IV. CONCLUSION

The results indicate that seasonal variation significantly influences vegetable crop productivity under backyard farming systems, with the Kharif season showing the highest yield potential, followed by Rabi and Zaid seasons. Backyard farming, when integrated with suitable crop selection and appropriate seasonal management, can serve as an effective strategy for sustainable food production in smallholder systems.

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