Intercropping - An Approach towards Sustainability in Dry Land Agriculture

Abstract

The scope for enhancement of productivity under irrigated conditions is limited due to over-exploitation of available resources However, there is ample opportunity for boosting yield in drylands by adopting suitable crops and cropping systems. The agricultural sustainability in drylands is comparatively hard to achieve due to different constraints like poor soil fertility, lack of irrigation facilities and moisture stress, small holdings and less investment in agriculture. In drylands, intercropping offers numerous opportunities to increase yield. Intercropping is the simultaneous planting of two or more crops in the same field. Intercropping is essential for improving the effectiveness of land use, weed control, ecological services, and economic viability. Improved yields and yield stability, better use of water and nutrients, increased weed control, increased pest and disease resistance, less soil erosion, and better feed quality are all advantages of intercropping. For maximising productivity in drylands, choosing ecologically sound crops like cereals and millets and implementing intercropping systems are two acceptable solutions. Ancient nutri-cereals known as millets have a significant impact on the nation's food and nutritional security and can provide agricultural sustainability in drylands when grown in intercropping systems. Most farmers who practise subsistence farming to secure their livelihoods choose the intercropping of wheat and legumes.

Key words: Agricultural sustainability, drylands, intercropping, small millets production and cereals

1. Introduction

Finding or creating suitable agricultural methods is required in every location of the world. Due to various biophysical, socioeconomic, and technological limitations, rainfed agriculture supports 40% of the world's population, uses 67 percent of the net sown area, and contributes 44% of the food grains (Swer and Dkhar (2014)). “Even after realization of full irrigation potential of the country, 50 percent of net sown area will continue as rainfed” (CRIDA, 1997). The limitations of dryland agriculture can be overcome by economically viable rainfed technologies such as integrated nutrient and pest management (INM and IPM), efficient crops and cropping systems that correspond to the growing season, suitable implements for timely sowing and labour savings, and soil and rainwater conservation measures. Intercropping is a promising technology for increasing dry land agriculture's production and profitability while fostering sustainability by strengthening soil health.

Intercropping in the larger framework of agronomic best practises and food security: Due to the rapid increase in population, there is a severe food scarcity in many regions of the world, particularly in India. Maximising the use of limited agricultural land through multiple cropping to boost productivity per unit area of arable land is one potential solution to this issue. (Seran *et al*., 2010; Khan *et al.*, 2014). For instance, it has been shown that intercropping legumes and barley increases productivity per available land area (Alizadeh and Teixeira da Silva, 2013). Intercropping, a widespread practise in developing countries (Wahla *et al.*, 2009) is an important multiple cropping system (Zhang and Li, 2003). The main benefit of intercropping is to increase yield on a particular plot of land by more effectively using the resources for growth that would otherwise go underutilised by each crop produced separately. To achieve sustainable agriculture, it is necessary to assess the range of studies done on intercropping. Thus, this review work has been made with the following objectives: **1.** to evaluate the scope of research made in an intercropping practice as an approach towards in dry land agriculture; **2.** to assess yield advantage of intercropping practice in the context of sustainable agriculture.

2. Intercropping

Growing two or more different crop species or various types concurrently in different row combinations or spatial arrangements on the same plot of land is known as intercropping. (Katyayan, 2005). To maximise productivity per square metre of land, two or more crops should be grown together. All environmental resources are used in the intercropping method to increase crop yield per unit area per unit time. The risk can be reduced by intercropping (Woolley and Davis, 1991). Efficiency of resource utilization can be increased with intercropping (Tilman *et al.,* 2002; Gao *et al.,* 2014). According to Sullivan (2003), Intercrops take use of changes in peak resource demands for nutrients, water, and sunlight by varying the maturity dates or development periods. Most studies found that intercropping used agricultural resources more efficiently than combining a solitary crop. Tsubo *et al.* (2001) carried out "a study to compare the production efficiency in intercropping (maize/been) with sole cropping (maize and been) in terms of radiation use efficiency (RUE). The authors concluded that the intercrop fraction of intercepted radiation and RUE was higher compared to sole cropping". Similar results were also observed by Awal *et al.* (2006) who reported "greater RUE in intercropping of maize/peanut in comparison with sole cropping of maize and peanut".

Because government farm regulations, contemporary crop varieties, agricultural equipment, and research activities are focused on producing monocultures rather than polycultures, intercropping systems have not been widely accepted. (Kirschenmann, 2007). Due to the substantial shortcomings of modern agriculture, interest in intercropping systems for the production of food and fibre has grown (Kirschenmann, 2007). Roberts *et al.* (1989) stated that wheat is the most suitable cereal for intercropping. To increase production, it is imperative to find the component crop with the highest yield advantage and best competitiveness.

3. Main aspects to be considered in intercropping systems

Several factors need to be taken into account before and during cultivation for intercropping to be successful. The component crops of a mixture must be carefully chosen, taking into account the local environment and the crops or varieties that are available. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Silwana and Lucas (2002) found intercropping affects vegetative growth of component crops, therefore have to consider the spatial (Willey and Rao, 1981a), temporal and physical resources. "Economically viable intercropping largely depends on adaptation of planting pattern and selection of compatible crops" (Seran and Brintha, 2009a). "Planting a crop with deep roots next to one with shallow roots, one that matures faster than another or one that requires only partial shade are examples of intercropping methods" (Fan *et al.*, 2006).

3.1. Maturity of crop

It is best to select crops with various maturation times so that a crop that matures quickly completes its life cycle before the start of a crop's main growth period. Staggered harvesting and the separation of grain commodities can also be aided by choosing crops or types with varying maturation times. This will allow the peak nutrient requirements of the component crops to be differentiated. Crops that mature at various times, separating their peak demands for nutrients, moisture, aerial space, and light, could be intercropped effectively (Enyi, 1977). Peak light need for maize in the maize-green gram crop occurs at 60 days after planting, while green gram is ready for harvest (Reddy and Reddi, 2007).

When the main crop and the intercrop grow at various times in order to meet their principal resource demands at different times, this will result in the highest yield advantage. Singh and Gupta (1994) stated that "competition between principal and subsidiary crop depends upon maturity period, canopy spread and rooting habit of component crops". Li *et al.* (2011) studied "intercropping system of wheat/ maize, wheat/ faba bean and maize / faba bean and observed that by using species having different maturity dates can be more effective in decreasing soil mineral nitrogen accumulation and increasing crop nitrogen use efficiency".

3.2. Time of planting

It has been established that the majority of intercropping systems commonly include cereal crops like maize. It frequently combines with other crops and seems to predominate as the intercrop's cereal component. (Maluleke *et al.,* 2005). "It is used as food, feed, and forage and is the third most significant cereal crop in the world after wheat and rice" (Kamara *et al.,* 2005). Ijoyah and Dzer (2012) in "an experiment to evaluate the yield of maize in a maize-okra mixture as affected by time of planting maize, reported that the greatest intercropped yield of maize was obtained when maize was planted at same time as okra". This result agreed with Muoneke and Asiegbu (1997) who reported that "best intercropped maize yield was obtained when planting was done at the same time as okra in a maize-okra mixture". Ijoyah and Dzer (2012) also reported that "intercropping maize and okra at same time produced the best okra yield compared to that obtained from monocropped okra". Mongi *et al.* (1976) found out that "planting maize with cowpea at the same time gave better maize yield".

3.3. Compatible crops

Intercropping requires careful consideration of the crop combinations. Monocrop production is decreased by plant density, shade, and nutrient competition between plants. In addition to spatial design, the best crops for utilising soil nutrients could be chosen to reduce plant competition. (Fisher, 1977b). "Numerous studies have demonstrated that intercropping can be more productive than monoculture, although intercropping can also lead to resource competition" (Humphries *et al.,* 2004; Harris *et al.,* 2008). "Among different resources of competition, light is one of them" (Egan and Ransom, 1996). "Soil moisture is another potential source of competition" (Humphries *et al.,* 2004). Competition between plants for nutrients is one factor that could affect the production of a mono crop. Spatial planning may lower crop competition. Numerous benefits result from mixing species in farming systems. These are expressed at different spatial and temporal scales, ranging from short-term increases in agricultural yield and quality to long-term increases in ecosystem stability (Malezieux *et al.,* 2009). "In intercropping, the right crop combination is crucial. When interspecific competition is lower than intraspecific competition and the component crops of an intercropping system compete for the same plant growth resources only partially, yield benefits result" (Vandermeer, 1989). "There is need to screen out the crop for compatibility with an objective to utilize maximum resources per unit area with maximum yield benefits and least competition between component crops". (Baidoo et al., 2012) Khan *et al.* (1999) revealed that "In comparison to solo crops, intercropping wheat and chickpeas in the ratios of 3:1 and 1:1 produced the highest seed production and monitory returns".

3.4. Plant density

Low plant population resulted into low yield (Jeyakumaran and Seran, 2007). Ghanbari-Bonjar and Lee (2003) demonstrated that When comparing intercrop to a single crop, the relative density of the component crops, the closeness with which the crops are intercropped, and the availability of scarce resources are all factors that can affect intercrop performance. Seran and Brintha (2010) reported that To achieve the best planting density, adjustments are performed to the component crops' seedling rates in the mixture. No change in yield has been observed when the rows' orientation is changed while maintaining the base crop's plant population per unit area (Sivaraman and Palainappan, 1996). “A reasonable leaf area index (LAI) is critical to maintain high photosynthetic rates and yield” (Xiaolei and Zhifeng, 2002). “Maize has diverse uses and the diversity of environment under which it is grown” (Doswell *et al.,* 1996). “It has high potential for carbohydrate accumulation per unit area per day” (Aldrich *et al.,* 1975). “Also the majority of intercropping systems are known to contain maize as a common element. It frequently combines with various legumes and seems to predominate as the cereal component of intercrop”. (Maluleke *et al.,* 2005).

4. Benefits of intercropping

4.1. Resource utilization

The major reason intercropping has a higher yield than a single crop is because it utilises resources like light, water, and nutrients more effectively (Liu *et al.* 2006). Gao *et al.* (2014) carried out study on Nitrogen utilisation efficiency was shown to be considerably higher in the wheat-maize intercropping system than in sole cropping . Zhang and Li (2003) conducted field experiments on Intercropping wheat with maize and wheat with soybeans increased nitrogen uptake by up to 50 and 59%, respectively, in the case of the wheat-maize intercropping and by 23 and 19%, respectively, in the case of the wheat-soybean intercropping. Barillot *et al.* (2014) found significantly Wheat and pea intercropping has a higher radiation usage efficiency than a single crop. It was linked to interactions between above- and below-ground systems.

Jiao *et al.* (2008) found maize-groundnut intercropping enhanced the efficient utilization of strong light by maize and weak light by groundnut lead to provide yield advantages. Li *et al.* (2001) stated that It is advantageous to intercrop in terms of productivity and nutrient uptake. They found that intercropping wheat with maize was beneficial up to 40–70% and intercropping wheat with soybean was advantageous up to 30%. Numerous benefits of intercropping include increased resource usage, decreased population of hazardous biotic agents, improved resource conservation and soil health, increased productivity, and system sustainability (Maitra *et al.,* 2019a; Maitra *et al.,* 2020). In intercropping system, more than one crop is grown together on the same land and utilizes the soil nutrients (Xue *et al.,* 2016; Yang *et al.,* 2018).

4.2. Weed control:

Intercropping resulted in lower weed infestation level (Liebman and Dyck, 1993). Szumalgaski (2005) described As intercrop obtains more light than solo crop due to its variable height and growing behaviour, it is said to be the most significant reason for weed suppression in intercropping systems.

Eskandari (2011) conducted field experiments on intercropped wheat and faba beans and found that the intercrop was more effective in suppressing weeds than wheat alone. He attributed this to the fact that weeds had less access to environmental resources in the intercropping system. Szumigalski and Van Acker (2005) observed When wheat-canola and wheat-canola-pea were intercropped, weeds were suppressed more effectively than in cases when they were the only crop. This suggested that intercrops of certain crops performed together to reduce weeds. Makindea *et al*. (2009) found leafy greens can be intercropped with maize to control weeds in the tropics and increase productivity. Weed suppression in maize groundnut intercropping was reported by Steiner (1984).

"Intercropping of maize with legumes considerably reduced weed density in the intercrop compared with maize pure stand due to decrease in the available light for weeds in the maize_-legume intercrops, which led to a reduction of weed density and weed dry matter compared with sole crops" (Langer *et al.,* 2007; Bilalis *et al.,* 2010). "Similarly, Weed population was reduced in wheat-faba bean intercropping" (Agegnehu *et al.,* 2008). Bibi and Khan (2014) also reported that "weed biomass was significantly affected by the intercropping treatments".

4.3. Pest and disease

Maize is susceptible to many insects (Drinwater *et al.,* 2002) and diseases (Flett *et al.,* 1996). For this reason, intercropping appears to be a very promising cultural practise. It is commonly accepted that one intercropping system's component crop may serve as a buffer or barrier against the spread of pathogens and pests. Intercropping maize and chick pea lowers stem borer populations (Hemik and Peeler, 1997). Maize leafhopper was reduced under intercropping as reported by Power (1990). Pino *et al*. (1994) found that pest and disease were less in tomato-maize intercropping. Soybean and groundnut are more effective in suppressing termite attack than common beans (Sekamatte *et al.,* 2003). Umarajini and Seran (2008) reported that the incidence of white fly and leaf hopper were lower in brinjal-groundnut intercropping compared to monocropping. Singh and Adjeigbe (2002) stated monocropping needs more chemical to control pest and disease than intercropping.

According to the findings of Degri *et al.* (2014), "intercrop patterns of 1:2 ratio and 1:1 ratio yielded less stem borer infestation and abundance in pearl millet, and as well supported high panicle weight and grain yield". "Similarly, intercropping maize-haricot bean reduces the stalk borer infestation on maize" (Ashenafi *et al*, 2015). Agegnehu *et al.* (2008) also found "intercrops were more suppressive of weeds and diseases than either wheat or faba bean sole crops". According to Tsubo *et al.* (2005), "By using the natural competitive principle, intercropping is an ecological way to control weeds, diseases, and insect pests. In terms of reducing and controlling pests and diseases, intercropping appears to be a very promising cultural practise. An intercropping system may have one crop that serves as a barrier to prevent the spread of pests and diseases".

4.4. Erosion control

By preventing raindrops from striking bare soil, where they have a tendency to plug surface pores, restrict water from penetrating the soil, and enhance surface erosion, intercropping reduces soil erosion. Cowpeas were the best cover crop for maize-cowpea intercropping, preventing soil erosion (Kariaga, 2004). Davidson (1994) described that Compared to most monocropping systems, a well-managed strip intercropping system has a larger potential for soil and water conservation. Chen *et al.* (2010) observed that Wind erosion, soil desertification, and deterioration can be significantly reduced by intercropping wheat and potatoes in strips up to 5 metres wide. Chen *et al.* (2010) concluded that Wind erosion was lessened as a result of the intercropping of wheat and potatoes. Additionally, they said that the effective width of the strip for wind erosion management should be larger than or equal to 5.5 metres. Sharaiha and Ziadat (2007) suggested that by promoting higher vegetative growth during critical erosive times, various cropping systems improve soil protection. Deep roots also break up hardpans in the soil and absorb moisture and nutrients from the soil's deeper layers. Shallow roots bind the soil near the surface together, preventing erosion and helping in soil aeration. There was less runoff and soil erosion in intercrops of legumes and maize (Kariaga, 2004).

4.5. Improvement of soil fertility

Problems with soil fertility are not just an agronomic problem; they are also closely tied to economic and social problems. Poor farmers often don't like taking risks and can't afford to make significant investments in fertility management. Intercropping is therefore beneficial for maintaining and improving soil fertility (Russell, 2002). This is reached when a cereal crop (such as maize) is grown in association with a pulse (beans, peas, *etc*). Legumes, commonly known as pulses, are excellent providers of protein. The primary source of nitrogen in legume-cereal mixed cropping systems when nitrogen fertiliser is scarce is biological nitrogen fixation (Lithourgidis *et al*., 2011; Fujita *et al.,* 1992). Moreover, legumes cultivated in intercropping are viewed as an alternative and sustainable approach to introduce N into reduced input agro ecosystems because inorganic fertilisers have led to environmental harm, such as nitrate pollution (Fustec *et al.,* 2010). Deep rooting pulse crops, such as pigeon pea also take up nutrients from deeper soil layers; thereby recycle nutrients leached from the surface (Adu-Gyamfi *et al.,* 2007; Rahman *et al*., 2009).

4.6. Risk spreading and food security

One important reason for which intercropping is popular in the developing world is that it is more stable than monocropping (Lithourgidis *et al*., 2011). Due to the diverse periods and patterns of growth, as well as different diseases that affect each crop, when two or more crops are cultivated on the same field, the risk for crop failure varies among the various crops (Tefera and Tana, 2002). Thus, If one of the crops fails (due to drought, flood, pests or diseases), there still is a harvest from the other crops (Lithourgidis *et al.*, 2011). Moreover, Farmers may be better able to deal with the seasonal price fluctuations of commodities, which frequently can cause their income to become unstable (Osman *et al.*, 2007). This ultimately increases food security (IPMS, 2005).

4.7. Promotion of biodiversity and stability:

One method of increasing biodiversity in agroecosystems is through intercropping, and results from intercropping research suggest that more diverse crop production may improve the amount of ecosystem services provided (Lithourgidis *et al*., 2011). By providing a habitat for a range of insects and soil organisms that would not be available in a single crop environment, intercropping of suitable plants increases biodiversity. Natural systems that are stable are usually varied, with a wide variety of plant species, arthropods, animals, birds, and microbes (Lithourgidis *et al*., 2011; Tsubo *et al.*, 2005). As a result, in stable systems, serious pest outbreaks are rare because natural pest control can automatically bring populations back into balance (Altieri, 1994). Therefore, on-farm biodiversity can result in agro-ecosystems that can maintain their own soil fertility, control organic pest control, and maintain productivity. (Thrupp, 2002; Scherr and McNeely, 2008).

4.8. Economic benefit of intercropping

Himasree *et al.* (2017) carried out an experiment in late *kharif* season on the acidic soils of the Rayalseema district of Andhra Pradesh and found that foxtail millet + pigeonpea (5:1) with sowing during the first week of August produced higher gross and net incomes and benefit-cost ratios. Contrary to producing just one crop, intercropping frequently yields superior financial returns (Wasaya *et al.*, 2013). Kalara and Gangwar (1980) reported that Intercropping helps in steadily raising farm income. Intercropping frequently resulted in higher combined yields and financial returns than either crop produced alone (Ahmad and Rao, 1982). Intercropping wheat and faba bean gave high net return compared to monocropping (Agegnehu *et al.*, 2008)

Khanzada *et al.* (2000) stated that In case of wheat and safflower intercropped with alternate 4 row strips, intercropping produced more economic return than monoculture. Verma *et al*. (1997) reported When intercropping wheat and Indian mustard, the highest net return, benefit cost ratio, and land equivalent ratio are all favourable. Intercropping occupies greater land use and provides higher net returns (Brintha and Seran, 2009). It provides higher cash return than growing one crop alone (Kurata, 1986). Ijoyah and Dzer (2012) also reported that the total yields and financial returns from intercropping were higher than those from either crop cultivated alone. Intercropping maize and cauliflower gave high net return compared to monocropping (Khatiwada, 2000). Sharma and Tiwari (1996) also reported that when maize and tomato were intercropped, the overall intercropped yields increased and the financial returns were higher than when the component crops were grown separately.

5. Problems of intercropping

Due to intense competition among component crop yields may be reduced. Competition occurs when two or more plants share the same growth factors, each of which is considerably below their combined demands and occurring in the same habitat (Thole, 2007). Basic variables that influence competition between component crops include morpho-physiological changes, agronomic characteristics, such as fertiliser treatment, sowing period, and crop combination proportion. The relative growth rates, growth times, and proximity of the roots of the various crops in rows where constituent crops are organised define the level of competition. In a cereal-legume intercrop, the cereal component has an advantage over the related legumes due to its faster growth rate, advantage in height, and more extensive root system (Ijoyah and Jimba, 2012).

6. Yield advantages in intercropping

Yield is taken as a primary consideration in the assessment of the potential of intercropping practices (Anil *et al.*, 1998). The yield of non-legume crops rose in intercropping when compared to monocropping when legume and non-legume crops were grown together (Brintha and Seran, 2008). Mashingaidze (2004) found that the intercropping strategy on land increased agricultural yield by efficiently using resources. Because of the improved yields and increased biological and economic stability in the system, the crops are grown together (Francis, 1986).

6.1. Land equivalent ratio (LER)

"This is the relative area of land under monocrop which is needed to obtain the yield produced in intercropping" (Wiley, 1979). Rao and Willey (1980) showed "A specific variation in the component crop's maturity period because of the benefit in yield, which obviously allowed good resource usage all through time". Khan *et al.* (1992) in "an experiment involving Because they were planted in the same rows, maize and soybeans had a high LER of 1.40, but the same crops were planted in alternate rows and had a low LER of 0.95". In Brazil, Raposa *et al.* (1995) recorded "high LER in intercrop involving 2:2 row arrangements than with monocrop". Yield advantages in maize-based intercropping were also reported in Ethiopia (Fininsa, 1997) that LER for intercrop was far above that of monocrop with maximal relative yield advantage of 28%. The most often used statistic for measuring land productivity in intercropping is the Land Equivalent Ratio (LER). "It is frequently used as an indicator to assess the success of intercropping" (Seran and Brintha, 2009b). "Maize-okra intercropping gave LER values of 1.84 and 1.80, respectively, in years 2009 and 2010" (Ijoyah and Jimba, 2012). "Maize sown at 50,000 plants per ha into okra plots gave the highest LER values of 1.83 and 1.86, respectively, in years 2010 and 2011" (Ijoyah *et al.*, 2012a).

6.2. Crop equivalent yield (CEY)

Saharan *et al.* (2018) noticed that "the Both the combinations of finger millet + pigeon pea and finger millet + black gram produced more finger millet equivalent yield (FMEY) than solo finger millet. The combined yield of finger millet and legumes was higher". **"**In a field experiment during *kharif* season conducted at Dharwad, Karmataka on alfisols clearly indicated that little millet + pigeonpea intercropping system of 5:1 row proportion recorded more dry weight, length of ear and grain weight" (Patil *et al.*, 2010). But the highest little millet equivalent yield (LMEY) was recorded with 4:2 row ratio. The study revealed that the Horse gram sequence was used after little millet + pigeonpea because it produced a greater little millet equivalent yield (LMEY). Similar results were also reported by Thesiya *et al.* (2019) under little millet-green gram cropping sequence.

6.3. Area time equivalent ratio (ATER)

"As a result, LER productivity estimates were higher than those of ATER in the maize + cowpea/soybean intercropping system, where yield advantages ranged from 22 to 32% based on LER technique and 19 to 25% based on ATER method over solo crops" (Allen and Obura, 1983). "The higher ATER (1.38) was recorded in the maize (maize and *Phaseolus vulgaris*) in 1:2 row ratio than *Phaseolus vulgaris* and maize grown as sole crops" (Gardner and Kisakye, 1990). At Pantnagar maize based intercropping systems, Halikatti and Banarasilal (1998) recorded higher ATER value (1.18) with one row of black gram followed by two rows of black gram between maize pairs compared to other cropping systems. Similarly, Pandita *et al*. (2000), also reported that at a 1:2 row ratio, maize and Phaseolus vulgaris produced the best maize equivalent yield (78.8 q ha-1) and highest ATER (1.48). Maize-based intercropping technologies are used in Dharwad.

6.4. Percentage (%) land saved

The percentage (%) land saved as described by Willey (1985) is another index used in assessing the advantage of intercropping system. It indicates the amount of land saved from intercropping, and which could be used for other agricultural purposes. It is formulated as: 100- 1/LER × 100. Ijoyah *et al.* (2012a) reported that "in the years 2010 and 2011, different maize plant densities up to 50,000 plants per hectare in a maize-okra intercropping system were saved, saving 45.4% and 46.2% of the lands, respectively". Khatiwada (2000) also reported that "50.8% and 48.2% of lands were respectively saved in 1999 and 2000, intercropping maize and cauliflower. Similarly, 44.4% and 43.2% of lands were respectively saved in 2010 and 2011, varying intra-row spacing of maize up to 30 cm in a maize-water melon intercrop".

6.5. Competitive ratio (CR)

The issue of crop competition arises because intercropping includes growing two or more crops together on the same plot of land. The CR measures how competitive the intercrop's different components remain (Willey and Rao, 1980). They proposed a measure that expresses the ultimate yields of the components corrected for the proportional areas on which the crops were sown. This measure is formulated as: CR= La/Lb, where La and Lb are the partial LERs of component crops. The competitive ratios were recorded higher for the different studies under intercropping.

7. CONCLUSION

Due to lower insect and disease incidence, less soil loss, and more effective use of nutrients, water, and solar radiation, smallholders' production in terms of harvestable products per unit area is generally higher than under solo cropping with the same level of management. These micro ecosystems support yields throughout the year, encourage biodiversity, and live without agrochemicals. Thus, For the purpose of developing intercropping systems that are compatible with existing agricultural methods and for a greater understanding of how intercrops work, further research is required. It has already been noted that thorough consideration must be given to the selection of the mixture's components if an intercrop combination is to be physiologically beneficial. If intercropping is done correctly, it can be a low-pollution type of farming because it uses less pesticides, fertilisers, and resources. These systems must undoubtedly provide advantages for smallholder farmers in terms of biological processes, the environment, the economy, and society for them to have existed.

It is well recognised that intercropping has the potential to provide numerous advantages, including increased resource usage, a decline in the number of hazardous biotic agents, higher resource conservation, improved soil health, and agricultural sustainability. In drylands, these advantages are particularly pronounced. Small millets, on the other hand, are significant dryland ecologically resistant crops that give smallholders food and nutritional security. Based on the research that has been reviewed and available, it can be concluded that intercropping small millets in drylands is one of the best methods for utilising environmentally friendly agriculture. Future research has plenty of room to expand, helping smallholder economies grow while maintaining agricultural sustainability in drylands.

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