Intercropping - An Approach towards Sustainability in Dry Land Agriculture

Abstract

The scope for enhancement of productivity under irrigated conditions is limited ~~because~~ due ~~of~~ toover-exploitation of available resources~~,~~ .~~but~~ 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.This paper reviews the scope of research made in an intercropping practice as an approach towards sustainability in dry land agricultureas well as yield advantage of intercropping practice in thecontext of sustainable agriculture.Intercropping is ample opportunity for boosting yield in drylands.Intercropping involves two or more crops in the same field at the same time.Intercropping plays a pivotal role for increasing land use efficiency, weed suppression, enhanced ecological services and greater economic profitability. Benefits of intercropping include improved yields and yield stability, enhanced use of water and nutrients, increased weed suppression, increased pest and disease resistance, reduced soil erosion and improved forage quality. Choice of ecologically sound crops as cereals, millets and adoption of intercropping systems are two of suitable options for maximization of productivity in drylands. Millets are ancient nutri-cereals which can play a crucial role in food as well as nutritional security of the country and can assure agricultural sustainability in drylands under intercropping system. The combination of cereal and legume in intercropping is mostly preferred by the farmers in subsistence farming targeting livelihood security.

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

1.Introduction

In every region of the world, it is necessary to find or develop appropriate techniques for agriculture. Indian economy is mainly dependent on agriculture, which contributes 15 per cent of the country's gross domestic product (GDP) and over 50 percent of population are still dependent on it (Ref??).The country will have to feed about 1.3 billion people by the year 2020 requiring 5-6 Mt of additional food grains every year.Rainfed agriculture occupies 67 percent of net sown area, contributing 44 percent of food grains and supporting 40 percent of total population due to a number of bio physical, socio economic and technological constraints (Ref??).Even after realization of full irrigation potential of the country, 50 percent of net sown

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area will continue as rainfed (CRIDA, 1997).Economically viable rainfed technologies such as soil and rainwater conservation measures, efficient crops and cropping systems matching to the growing season, suitable implements for timely sowing and saving of labour, integrated nutrient and pest management (INM and IPM) can overcome the constraints of dryland agriculture.Intercropping is a promising technology for enhancing land productivity and profitability of dry land agriculture and imparting sustainability ~~to it~~ through improving soil health.

Intercropping in the broader context of food security and good agronomic practice: Food shortage is prevalent in many parts of world, particularly in~~india~~India, due to the rapid rise in population. One possible approach to resolve this problem would be to maximize the utilization of limited agriculture land through multiple cropping to increase productivity per unit area of available land (Seran*et al*., 2010; Khan *et al*., 2014~~), ~~).~~for~~ For ~~which there are many examples, e.g.~~ instance, intercropping of legumes and barley have been reported to increase productivity per unit area of available land (Alizadeh and Teixeira da Silva, 2013). Intercropping, which has long been a common practice in developing countries (Wahla*et al.,* 2009) is an important multiple cropping system (Zhang and Li, 2003). The most common advantage of intercropping is to produce a greater yield on a given piece of land by achieving more efficient use of the available growth resources that would otherwise not be utilized by each single crop grown alone. Therefore there is need of reviewing the scope of research made in an intercropping to achieve sustainable agriculture. Thus, this review work has been made with the following objectives~~:-~~:**1.**~~To~~ to evaluate the scope of research made in an intercropping practice as an ~~Approach~~ approach towards ~~Sustainability~~ sustainability in ~~Dry~~ dry ~~Land~~ land ~~Agriculture~~agriculture;**2.**~~To~~ to ~~summarize significance and~~assess yield advantage of intercropping practice in thecontext ofsustainable agriculture.

2.Intercropping

Intercropping is a system of management of crop which involves growing of two or more dissimilar crop species or varieties simultaneously in distinct row combination or spatial arrangement on the same piece of land (Katyayan, 2005). The important reason to grow two or more cropstogether is ~~the~~ toincrease ~~in~~ productivity per unit of land. Inintercroppingsystem,alltheenvironmentresourcesare utilized to maximize crop production per unit area per unit time. Risk may be minimized in intercropping (Woolleyand Davis, 1991). Biological efficiency of intercroppingduetoexplorationoflargesoilmasscomparedtomonocropping(Francis,1989).Efficiency of resource utilization can be increased with intercropping (Tilman *et al.,* 2002; Gao *et al.,* 2014). According to Sullivan (2003), intercrops staggered the maturity dates or development periods and take advantage of variations in peak resource demands for nutrients, water, and sunlight. In comparison with corresponding sole crop, higher agricultural resource utilization of intercropping was observed in most studies. 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.

Wide spread acceptance of intercropping systems have not occurred because agriculture technology, modern crop varieties, government farm policies and research efforts are concentrated on production of monocultures not poly cultures (Kirschenmann, 2007). Due to significant drawbacks in modern agriculture system, interest in intercropping system has developed for the production of food and fiber (Kirschenmann, 2007). Roberts *et al.* (1989) stated that wheat is the most suitable cereal for intercropping. There is immense need to identify the component crop with high yield advantage and good competitive ability to maximize production.

3.Main aspects to be considered in ~~an~~ intercropping ~~–~~systems

Successful intercropping needs several considerations before and during cultivation. Careful planning is required when selecting the component crops of a mixture, taking into account the environmental conditions of an area and the available crops or varieties. 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). Examples of intercropping strategies are planting a deep -rooted crop with a shallow-rooted crop, early maturing crops with long maturing crops or planting a tall crop with a short crop that requires only partial shade (Fan *et al.*, 2006).

3.1.Maturity of ~~Crop~~crop~~:~~

When two or more crops are growntogether the peak period of growth of components does notcoincide.The biggest complementaryeffects and thusbiggestyieldadvantagesseentooccurwhenthecomponent crops have different growing periods ~~so~~ to ~~make~~facilitatetheir major demands on resources at different times (Ref??). Cropsof varying maturity duration should be chosen ~~therefore~~so thata rapidly maturing crop completes its life cycle before themajor growth period of other crop commences. Selectingcrops or varieties with different maturity time can alsoassiststaggeredharvestingandseparationofgraincommodities. By this, the time of peak nutrient demandsofcomponentcrops should be differed.Cropswhichmature at different times thereby separating their periodsof maximum demand to nutrient and moisture aerial spaceand light could be suitably intercropped (Enyi, 1977). Inmaize-greengram, peak light demand for maizeisaround60 days after planting, while greengram is ready to harvest(ReddyandReddi,2007).

There will be biggest yield advantage, when main crop and intercrop have different growing period in order to make their major demand of resources at different times. 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

Cereal crop such as maize, ~~have~~ hasbeen recognized as a common component in most intercropping systems. It seems to dominate as the cereal component of intercrop and often combined with other crops (Maluleke *et al.*, 2005). It is the third most important cereal crop following wheat and rice in the world production and used as food, feed and forage (Kamara *et al.*, 2005). Intercropping with maize is a way to grow a staple crop while obtaining several benefits from the additional crop. 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~~:~~

Choosing of the crop combinationplays vital role in intercropping. Plant density, shadingandnutritioncompetitionbetweenplantsreducetheyieldof monocrop. Plant competition could be minimized notonly by spatial arrangement, but also by choosing thosecropsbestabletoexploitsoilnutrients(Fisher,1977b). Many studies have ~~been~~ shown that intercropping can be more productive compared to monoculture but intercropping can result into competition for resources (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). Among other sources,; there is competition for nutrients between plants that could reduce the yield of mono crop. Crop competition can be reduced by spatial arrangement. Mixing species in cropping system leads to lots of benefits. These are expressed on various space and time scales, from increase in crop yield and quality on short term basis and ecosystem sustainability on long term basis (Malezieux*et al.*, 2009). Proper combination of crop is very important in intercropping. Advantages in terms of yield occur when component crops of intercropping system compete only partly for the same plant growth resources and inter-specific competition is less than intra-specific competition (Vandermeer, 1989). There is need to screen out the crop for compatibility (Baidoo *et al.*, 2012) with an objective to utilize maximum resources per unit area with maximum yield benefits and least competition between component crops. Khan *et al.* (1999) revealed that intercropping of wheat and gram grown in ratio of 3:1 and 1:1 resulted into maximum seed yield and monitory returns as compared to sole crops.

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3.4.Plant density:

Low plant population resulted into low yield (Jeyakumaran and Seran, 2007). Ghanbari-Bonjar and Lee (2003) demonstrated that while comparing intercrop to sole crop, success of intercrop can be determined by lot of agronomic practices including; relative density of component crops, the intimacy with which crops are intercropped and supplies of limited resources. Seran and Brintha (2010) reported that adjustment is made in seedling rate of component crops in mixture to optimize the planting density. Keeping the plant population per unitarea of the base crop constant, no deviation of its yieldhas been noted by altering the orientation of the rows(Sivaraman and Palainappan, 1996). A reasonable Leaf leaf AreaareaIndex index (LAI) is critical to maintain high photosyntheticratesandyield(XiaoleiandZhifeng,2002).Maizehasdiverseusesandthediversityofenvironment under which it is grown (Doswell *et al*.,1996). It has high potential for carbohydrate accumulationper unit area per day (Aldrich *et al.*, 1975). Also maize hasbeenrecognizedasacommoncomponentinmostintercropping systems. It seems to dominate as the cerealcomponent of intercrop and it is often combined withdifferent legumes (Maluleke *et al.*, 2005).

4.Benef1tsBenefitsofintercropping

4.1.Resource utilization:

Yield advantage in intercropping is mainly due to efficient utilization of resources such as light, water and nutrients than respective sole crop (Liu *et al.* 2006). Gao *et al.* (2014) carried out study on wheat- maize intercropping system and revealed that Nitrogen use efficiency was significantly higher in intercropping compared to sole cropping. Zhang and Li (2003) conducted field experiments on wheat- maize and wheat-soybean intercropping and observed that there was increase in uptake of nitrogen up to 50 and 59%, respectively in case of wheat-maize intercropping, respectively and 23 and 19% in case of wheat-soybean intercropping, respectively. Barillot*et al*. (2014) found significantly higher radiation use efficiency in wheat-pea intercropping than that of sole crop. It was attributed to above ground and below ground interaction.

Jiao *et al*.(2008)foundmaize-groundnutintercroppingenhancedtheefficient utilization of strong light by maize and weak lightby groundnut lead to provide yield advantages. Li *et al.* (2001) stated that intercropping is advantageous in terms of yield and nutrient acquisition. They observed that it was advantageous up to 40-70% in case of wheat intercropped with maize and 28-30% in case of wheat intercropped with soybean. Intercropping is advantageous in many ways as it assures greater resource use, reduction of population of harmful biotic agents, higher resource conservation and soil health and more production and sustainability of the system (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~~control:

Intercropping resulted in lower weed infestation level (Liebman and Dyck, 1993). Szumalgaski (2005) described most important cause of weed suppression in intercropping system and stated that as intercrop captures more light than sole crop due to its different height and growing habit. Eskandari (2011) conducted field experiments on intercropping of wheat and faba bean and reported that intercrop was more effective in weed suppression than wheat sole crop and he attributed this to less availability of environmental resources to weeds in intercropping system. Szumigalski and Van Acker (2005) observed greater weed suppression in case of intercrop as compared to their sole crop when wheat-canola and wheat- canola- Pea were intercropped. This indicated some sort of synergism among crops within intercrops regarding weed suppression.Makindea*etal*.(2009)foundleafygreenscanbeintercropped with maize to control weeds in the tropicsand increase productivity. Weed suppression in maizegroundnut 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).Intercroppingappears to be a very promisingculturalpractice for this purpose. It is generally believed that onecomponent crop of an intercropping system may act as abarrier or buffer against the spread of pests and pathogen.Intercroppingmaize-chick peareducesthestemborer(Hemikand Peeler, 1997).Maizeleafhopperwasreducedunder intercroppingas reportedbyPower (1990). Pino *et al.* (1994) found that pest and diseasewere less in tomato-maize intercropping. Soybean andgroundnut are more effective in suppressing termite attackthan common beans (Sekamatte*et al.*, 2003). Umarajiniand Seran (2008) ~~stated~~ reported thatthe incidence of white fly and leafhopper were lower in brinjal-groundnut intercroppingcompared to monocropping. Singh and Adjeigbe (2002)stated monocropping needs more chemical to control pestanddiseasethanintercropping.

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~~ 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), intercropping is an ecological method to manage insect pest, diseases and weeds via natural competitive principle. Intercropping promises to be a very promising cultural practice in the reduction and control of pests and diseases. One component crop of an intercropping system may act as a barrier against the spread of pests and diseases.

4.4.Erosion control~~:~~

Intercropping controls soil erosion bypreventing rain drops from hitting the bare soil where theytend to seal surface pores, prevent water from entering thesoilandincreasesurface~~eros10n~~erosion.~~Maize~~In maize-cowpeaintercropping, cowpea acted as best cover crop and reducedsoil erosion (Kariaga, 2004). Davidson (1994) described that well managed strip intercropping system could result into greater soil and water conservation potential than most of the monocropping systems. Chen *et al.* (2010) observed that intercropping of wheat and potato grown in strips up to 5m can reduce wind erosion, soil desertification and degradation effectively. Chen *et al.* (2010) concluded that wheat-potato intercropping resulted into reduction in wind erosion. They also stated that effective width of strip for control of wind erosion should be greater than or equal to 5.5 m~~eters~~.Sharaiha and Ziadat (2007) suggested that multiple cropping systems increase the soil protection by increased vegetative growth during critical erosion periods. More~~e~~over, deep roots penetrate far into the soil breaking up hardpans and use moisture and nutrients from deeper down in the soil.

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Shallow roots bind the soil at the surface and thereby help to reduce erosion and help to aerate the soil. Reduced runoff and soil loss were observed in intercrops of legumes with maize (Kariaga, 2004).

4.5.Improvement of soil fertility

Soil fertility problems are not only an agronomic issue, but also strongly related to economical and social issues. Poor farmers are typically risk adverse and cannot afford to make large investments in relation to fertility management. Thus, an important reason for intercropping is the improvement and maintenance of soil fertility (Russell, 2002). This is reached when a cereal crop (such as maize) is grown in association with a pulse (beans, peas, etc). Pulses also called legumes are protein rich sources of food. When nitrogen fertilizer is limited, biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems (Lithourgidis*et al*., 2011; Fujita *et al.,* 1992). Moreover, because inorganic fertilizers have contributed to environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as an alternative and sustainable way of introducing N into lower input agro ecosystems (Fustec*et al.,* 2010). Deep rooting ~~Pulse~~ 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).

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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). When two or more crops are grown on the same field, the risk for the crop failure is spread over the different crops as the different crops have different periods and patterns of growth, and are affected by different diseases (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 cope with seasonal price variability of commodities which often can destabilize their income (Osman *et al.,* 2007). This ultimately increases food security (IPMS, 2005).

4.7.Promotion of biodiversity and stability:

Intercropping is one way of introducing more biodiversity into agro ecosystems and results from intercropping studies indicate that increased crop diversity may increase the number of ecosystem services provided (Lithourgidis*et al*., 2011). Intercropping of compatible plants promotes biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. Stable natural systems are typically diverse, containing numerous different kinds of plant species, arthropods, mammals, birds, and microorganisms ~~(~~(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 lead to agro-ecosystems capable of maintaining their own soil fertility, regulating natural protection against pests, and sustaining productivity (Thrupp, 2002; Scherr and McNeely, 2008).

4.8.Economic benefit of intercropping

Himasree*et al.* (2017) carried out an experiment in late kharif conditions in acidic soils of Rayalseema region of Andhra Pradesh and concluded that more gross and net incomes and benefit-cost ratio were obtained with the sowing of foxtail millet + pigeonpea (5:1) with sowing during first fortnight of August.Intercropping often provides higher cash return than growing one crop alone (Wasaya *et al.*, 2013). Kalara and Gangwar (1980) reported that intercropping helps in increasing farm income on sustained basis. Intercropping commonly gave greater combined yields and monetary returns than obtained from either crop grown alone (Ahmad and Rao, 1982). Intercropping wheat and faba bean gave high net return compared to monocropping (Agegnehu*et al.*, 2008)

Comment [p4]: Do you mean kharif season?

Khanzada *et al.* (2000) stated that intercropping gave higher economic return than monoculture in case of wheat and safflower intercropped with alternate 4 row strips. Verma *et al*. (1997) reported maximum net return, benefit cost ratio and land equivalent ratio in case of intercropping of wheat and Indian mustard. 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 intercropping gave greater combined yields and monetary returns than those obtained from either crop grown alone. Intercropping maize and cauliflower gave high net return compared to monocropping (Khatiwada, 2000). Sharma and Tiwari (1996) also reported that maize intercropped with tomato increased total intercropped yields and gave greater monetary returns than those obtained from the component crops grown as sole.

5.Problems of ~~Intercropping~~ intercropping

Reduction in yield of component crop may occur due to intense competition. The situation in which two or more plants share the same growth factors each far below their combined demands and in the same environment is known as competition (Thole, 2007). The basic morpho-physiological changes and agronomic features such as fertilizer application, sowing time, and proportion of crop mixture are basic determinants of competition between component crops. Where constituent crops are arranged in certain rows, the degree of competition is determined by the comparative growth rates, growth duration and proximity of roots of the diverse crops. The cereal component in a cereal-legume intercrop has advanced growth rate, height advantage, and a more widespread rooting system which gives it upper hand in competition with associated legumes. Ofori and Stern (1987) reported that the yield of the legume component declinedon normalby about 52% of the sole crop yield, whereas the cereal yield was condensed by only 11%. Significantly, it was noted that the cereal constituent depresses the legume in an intercrop. This was attributed to abridged photosynthetic active radiation of the legume by the screening from cereal crop.

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6.Yield advantages in intercropping

Yield is taken as a primary considerationintheassessmentofthepotentialofintercroppingpractices (Anil *et al.*, 1998). In legume and non -legumeintercropping,yieldofnon-legumes increasedinintercroppingas compared with monocropping (BrinthaandSeran,2008).Mashingaidze(2004)foundthatbyintercroppingsystem on land was effectively utilized resources and thereby improving cropyield wasimproved.Thecropsaregrown togetherbecause ofhigher yields and greater biological and economic stabilityinthesystem(Francis,1986).

6.1. Land Equivalent equivalent Ratio 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 clear variation in duration of maturity of component crop was due to largely the advantage in yield, which clearly allowed in this combination for a good resource use with time. Khan *et al.* (1992) in an experiment involving maize and soybean recorded a high LER of 1.40 as a result of sowing them in same rows, while a low LER of 0.95 involving the same crops was noted but on alternate rows. 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%. LandEquivalentRatio(LER)isthe most common indexadoptedin intercroppingtomeasurethelandproductivity.Itisoftenused as anindicatortodeterminethe efficacy 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 hectare hainto 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 equivalent Yield yield (CEY)

Saharan *et al.* (2018) noticed that the combined yield of finger millet and legumes was more and both the combinations of finger millet + pigeon pea and finger millet + black gram produced more finger millet equivalent yield (FMEY) than sole finger millet.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 higher little millet equivalent yield (LMEY) was noted in little millet + pigeonpea with 6:1 row proportion followed by horse gram sequence. Similar results were also reported by Thesiya*et al.* (2019) under little millet-greengram cropping sequence.

6.3.Area ~~Time~~ time ~~Equivalent~~ equivalent ~~Ratio~~ ratio (ATER)

In maize + cowpea/soybean intercropping system, the yield advantages ranged from 22 to 32%~~per cent~~ based on LER method 19 to 25%~~per cent~~ based on ATER method over sole crops and thus LER productivity estimates were greater than that of ATER (Allen ~~&~~andObura, 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 ~~&~~andKisakye, 1990). At Pantnagar~~, in~~ maize based intercropping systems, Halikatti and Banarasilal (1998) recorded higher ATER value (1.18) with one row of blackgram followed by two rows of blackgram between maize pairs compared to other cropping systems. Similarly, Pandita *et al*. (2000), also reported that maize and *Phaseolus vulgaris* at 1:2 row ratio gave the maximum ATER (1.48) with highest maize equivalent yield (78.8 q ha^{-1}). At Dharwad~~, in~~ maize based intercropping systems, Mohan (2003) recorded higher ATER value (1.65) with two rows of rice bean between maize spaced at 90 cm followed by two rows of soybean (1.63) and French bean (1.51) compared to other cropping systems

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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 ×~~x~~ 100. Ijoyah*et al.*~~,~~ (2012a) reported that 45.4 % and 46.2% of lands were respectively saved in years 2010 and 2011 varying maize plant densities up to 50,000 plants per hectare in a maize-okra intercropping system. 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)

Since intercropping involves growing two or more crops together on the same land area, the question of competition between the crops arises. The CR measures the degree of competition between the components of the intercrop (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

In most multiple cropping systems by smallholders, productivity in terms of harvestable products per unit area is higher than under sole cropping with the same level of management due to reduction of pest incidence, diseases, soil loss and more efficient use of nutrients, water, and solar radiation. These micro ecosystems promote biodiversity, thrive without agrochemicals, and sustain year-round yields. Thus, more research is needed to better understand how intercrops function and to develop intercropping systems that are compatible with current farming systems. It has been emphasized already that for an intercrop combination to be biologically advantageous, the mixture components need to be chosen with care. If intercropping is soundly practiced, it requires less pesticides and fertilizers, less capital and therefore can be a low-polluting method of farming. Obviously, to have persisted with smallholder farmers, these systems ~~had to~~must possess~~have merit~~ biological~~ly~~, environmental~~ly~~, economical~~ly,~~ and sociological~~ly~~ benefits to them.

The potential of intercropping is well known for multifaceted benefits like greater resource use, reduction of population of harmful biotic agents, higher resource conservation and soil health and agricultural sustainability. These benefits are prominently pronounced in drylands. On the other hand, small millets are important ecologically hardy crops of drylands which ~~can~~ provide food and nutritional security to smallholders. On the basis of available literature studied, it can be ~~said~~ deduced that intercropping small millets in drylands is one of the suitable options to harness ecologically sound agriculture. There is enough scope for future research which can further boost economy of smallholders with agricultural sustainability in drylands.

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