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Review Article

Agricultural production system in arid and semi-arid regions

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Abstract

The arid and semi-arid regions comprise more than forty percent of the Earth's land surface on which a large number of people situated and largely engaged in agriculture to meet their basic needs. However, agriculture in these regions are highly influenced by several factors including water limitation, extreme heat, frequent drought, bare and marginal soil, vulnerable topography for natural hazards, erosive rain and wind. In order to cope with these challenges a number of essential scientific investigation and cultural practices have continuously released, modified and recommended to sustain agriculture production in these regions. Some of these indispensable investigation and practice included that soil and water conservation, rain water harvesting and supplementary irrigation, use of stress tolerant crops and integrating of diverse farming system. So in this review it is attempted to discuss several points concerning arid and semi-arid land agricultural constraints and management action carried out to solve such constraints.

Introduction

Arid and semi-arid regions are characterized by hostile environmental conditions that include low and erratic rainfall, high wind velocity, intense solar radiation and high potential evapotranspiration during most parts of the year [1,2]. Arid lands cover about 41 percent of the earth's terrestrial surface and are home to more than a third of all human being in the world [3].

The situations in arid and semi-arid tropical areas are likely to have increased risks and vulnerabilities due to climate change [4]. The main causes of the existence of these climates are the low frequency of adiabatic rise of large bodies of air and the remoteness from an oceanic source of moisture [5]. The agriculture in these regions is facing multiple and complex challenges in terms of decline in factor productivity and the degradation of natural resources [2]. Due to various natural and anthropogenic factors affecting agricultural production, many arid and semi-arid regions are food insecure [6]. In such regions the production of adequate and renewable supplies of food, fodder and firewood is critically limited by the scarcity of water [7]. Limited and erratic precipitation often results in low crop yields and sometimes in total crop failure [8].

Soil degradation issue is one of the most important factors that threaten the crop production thereby reflecting on food

security particularly in arid and semi-arid regions [9]. Many countries in arid and semi-arid lands of Sub-Saharan Africa are challenged by land degradation, low water productivity and high rainfall variability which are often associated with climate change [10,11]. Land degradation is a major cause for poverty in rural areas of developing countries [12]. Mitigation of land degradation impacts depends on understanding the natural cause of degradation [9]. For example extensively cultivated on steeply slope farmlands has led to highly susceptible to water erosion in the rainy seasons [13,14] that resulted decline in soil productivity [15]. Land degradation and rainfall variability are severe problems affecting such farmlands so that various landscape restoration and soil and water conservations are essential practices for such area [16]. On other hand Wind erosion is a major land degradation problem in arid and semi-arid regions where irregular and insufficient precipitations, high wind speeds, smooth surface topography, light soil texture, poor aggregation and poor vegetation cover is common [17,18]. Wind erosion and resultant dust emissions create significant risks for land degradation and ecosystem health in arid and semi-arid regions [18]. Minimum tillage and crop rotation has significant impacts on protecting soil surface against wind erosion [18]. So appropriate soil conservation that integrating biophysical aspects and socio-economic parameters are needed in dryland ecosystems [9].

Not only soil and water conservation is enough to cope with harsh condition in arid and semi-arid land agricultural production but also other agronomic practices and adopting of various agricultural production techniques contribute significant roles. Changing cropping patterns, irrigation, rearing livestock as mixed farming, and agro forestry based adaptation strategies are another means of income sources for the livelihoods of households in arid and semi-arid regions [19].

Thus in order to meet diverse need of agricultural products of a growing population, it is necessary to find or develop appropriate techniques for agriculture in every region of the world. Particularly, in arid and semi-arid regions, where natural risks have frequently occurred, more viable food-producing agricultural systems that can be mastered by the local population are required. For this reason, arid zone agriculture is the subject of much research because of the increasing interest in the agricultural problems of developing countries, many of which are located in the arid and semi-arid regions of the world [20].

In this paper it is attempted to overview the role of soil and water conservation and farming technique across arid and semi-arid regions. Key constraints faced in these regions and ways to overcome these constraints are also discussed.

Objective

The objective of this paper is to review main constrains of arid and semi-arid regions and farming technique carried out in these regions to overcome these constraints.

Principal arid regions of the world

Deserts are large bands of dry lands along the tropics in both the Northern and Southern hemispheres [21,22]. The main characteristic of world deserts is aridity. Some of the larger arid regions in the world are Sahara Desert, Kalahari Desert,

East Africa and Sahel in Africa; Thar Desert, Namub Desert, Karakum Desert, Gobi Desert and Middle east in Asia; Atacama Desert and Serrano of Brazil in South America; Sonora Desert and Much of Western USA in North America; the pacific Coast in Central America; and the Central Deserts in Australia [23]. Although these regions may comprise the most arid regions, there are many more areas where aridity is rapidly expanded Figure 1.

Much of the world's dry lands are in developing countries and characterized by low crop productivity, limited irrigation potential, weak administrative and agricultural research infrastructures [24,25]. Ensuring higher productivity and profitability, gainful employment and adequate supply of food, feed, fodder and fiber for a growing human and livestock population, along with maintaining environmental sustainability are major challenges in agricultural production systems of arid and semi-arid regions [2].

However, many studies in arid and semi-arid regions have provided several improved and suitable agricultural systems for such marginal environments and technique how societies cope with marginal environmental circumstances; and about the effects of the environmental conditions on agricultural production, sustainability and life of population as discussed below.

Major crop production constraints in arid regions

Water limitation: Many of the impoverished people live in semi-arid mixed farming regions depend on natural resources for their survival. In this region rainfall is low and erratic, droughts are frequent, and soils are poorly structured and infertile [26]. For semi-arid regions, where the normal annual rain fall is below the minimum crop water requirement, crop could potentially face acute water stress during sensitive stages of crop development, i.e. flowering and grain filling, often leads to devastating effects on crop yields [19]. Drought

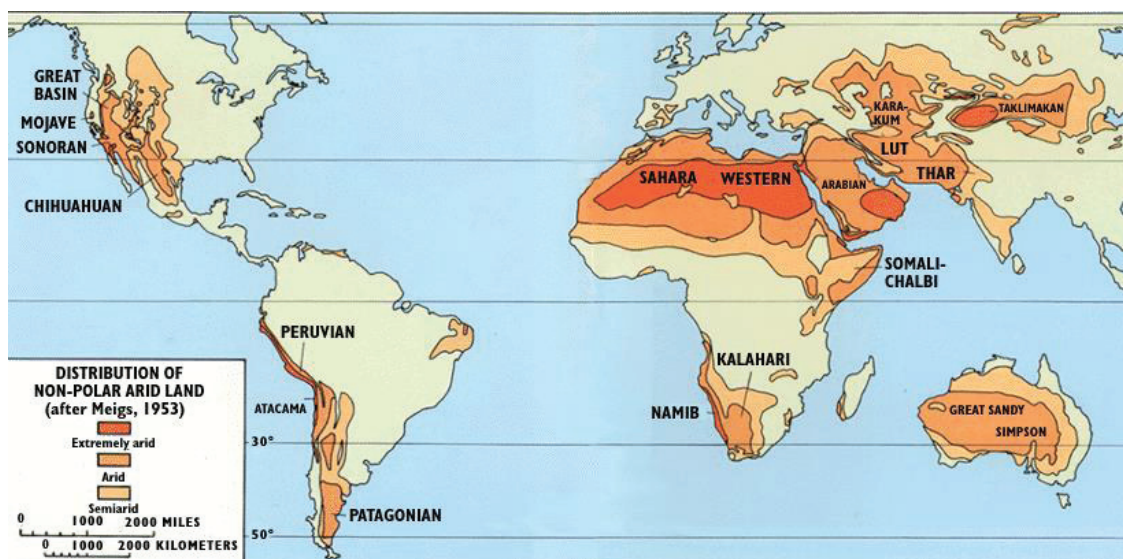


Figure 1: Distribution of arid land in the world.

Source: <http://pubs.usgs.gov/gip/deserts/what/world.html>.

is a common phenomenon, affecting about 100 percent of the land in Somalia, Eritrea and Djibouti, Ethiopia, Kenya and Sudan [27,28]. The agriculture sector is highly vulnerable to drought, as it depends directly on water availability [29,30]. For these reasons the vulnerability of agricultural production to extreme events and the quantification of drought impacts on crop yields have become a focus of interest [30]. When the statistical crop yield are influenced by drought, they may also be adversely affected by other natural factors such as pest, frost, floods, and other natural disasters [31]. Yield loss risk tends to grow faster when experiencing a shift in drought severity from moderate to severe. When experiencing an exceptional drought, the probability of yield loss could exceed 70% for soybean and maize, while the risk for wheat and rice is up to 68% and 64%, respectively [32]. Similarly, unbalance energy and environmental stress (nutritional, photo-periodical and thermo-periodical factors) have reduced the reproductive efficiency of animals in arid and semi arid regions [33]. Water shortage, heat stress and feed shortage impacts cattle production severely during drought periods [34].

The quality, quantity and distribution of water available in arid and semi-arid regions are also under influences of several factors. In these regions the rains are highly variable in time, space, amount and duration, and water is the most important limiting factor for biological and agricultural activities [1]. Lack of rainfall or the short periods of rainfall during crop productive stage have led to severe crop failures in semi-arid lands over the past decade [35]. Delay in onset of main rain fall or long dry spells after early sowing; long gaps between two successive rains in the vegetative stages ; early cessation of rainfall and crop water stress at maturity stage are most common crop production constraints in arid and semi-arid regions. Frequent dry spells and droughts exacerbate the incidence of crop failure and hence food insecurity and poverty [3,37].

Water that falls in these regions may be of little use for crop plants because the amount is too small to penetrate the soil sufficiently, or it may run through a porous soil too quickly, or it may run off too quickly [23]. Short rainfall duration with high intensity and poor surface vegetation coverage have aggravated rapid flooding in semi arid regions [38,39].

Moreover, water bodies in arid and semi-arid regions like rivers, lakes and wells may have problems of quality, especially the presence of excess minerals; use of this water bodies for irrigation might lead to the accumulation of salts in the soil resulting in alkalinity or salinity, which might then limit crop production [23]. Salt-affected lands are mainly located in arid, semi-arid lowland dry areas where rainfall is neither sufficient nor reliable for sustainable crop production [40]. In these regions, the impact of alkalinity or salinity can be exacerbated by the high evaporative rate, which concentrates the mineral components supplied by the irrigation water [41].

On other hand short season heavy rainfall severely eroded and remove huge amount of fertile soil every year. High loss of soil and rainfall water occurs during high intensity rains and poor crop rooting conditions at early crop stages due to high surface runoff [42]. This ultimately jeopardizes the livelihoods of farmers due to reduction in crop yield and income.

In many of the world's agricultural areas Sustainable and economically viable crop production depends largely on nitrogen application through external sources [43]. However, the application of a substantial amount of N has environmental negative impacts. The environmental acidification increased primary because of increased in nitrogen fertilizer [44]. Agricultural pollutants like fertilizers and pesticides, which have devastating effects on aquatic ecosystem and ground water pollution, reach to water bodies through runoff after rain and flood [45,46]. Several models have developed to quantify these potential environmental impacts associated with agricultural production like fertilizer and pesticides emissions by using life cycle assessment of agricultural products [47- 49].

Extreme heat and wind erosion

The major effects of heat and wind are to increase the rate of evaporation of water, and thus increase the effects of aridity. High air temperature dries the soil rapidly and increases wind erosion potential [50]. Wet soils are not subject to wind transport as the soil particles have attached together by cohesion forces.

Wind erosion is the result of a combination of many factors associated with climate, soil, land surface, and management conditions. Wind velocity, vegetative cover, soil surface moisture, surface roughness, aggregate stability, soil texture and rock volume fraction are the most important parameters influencing wind erosion [51].

It is obvious that fast and continuous winds cause more erosion than slow winds with less frequent. Wind erosion is most common, and often most serious, in semiarid or arid regions, where vegetative cover is scarce or absent [52]. Evaporation from bare soils results in a considerable loss of moisture and has a direct impact on crop yield in rain fed agriculture of arid and semi-arid regions [53].

Intensive tillage also rapidly changes soil stability as it breaks, inverts, mixes, and pulverizes aggregate soil. The more the soil surface is disturbed by cultivation in the absence of crops, usually the greater is the opportunity for wind to transport it [52].

Soil problems

Soils surface under annual field crops remains bare for long dry season resulting loss of soil moisture content, disintegrated soil particles, or dust formation that is easily vulnerable for erosion. The strong relationship observed between the topsoil moisture content and the number of erosive days was suggested as a noticeable mitigation effect for Wind erosion [54]. Evaporation from bare soils results in a considerable loss of moisture and has a direct impact on crop yield in rain fed agriculture of arid and semi-arid regions [53].

This is even more urgent in arid and semi-arid regions, characterized by highly variable and often chronically deficient rainfall [23]. In these regions, plant residues often are used for multipurpose including livestock feed, fuel, shelter and manufacturing purposes so that residue availability decreases

sharply in hot and dry regions resulting in a sharp drop in soil productivity [55].

Another common challenge in the arid and semi-arid land is Soil salinity. It is a complex dynamic process with serious consequences for the soil environment as well as, geochemical, hydrological, climatic, agricultural, and economic impacts [56]. Soil salinity is a serious global environmental problem that adversely affects soil and water quality, crop growth and productivity especially in arid and semiarid areas [56,57]. The arid and semi-arid low land agro-ecologies are regarded as marginal environments for crop production mainly due to soil and water salinity [40]. Low amount of annual rainfall and high daily temperatures have aggravated water evaporation rates consequently high concentrations of soluble salts in lowland areas has situated [58]. Thus soil degradation caused by various factors reduces soil productivity and is a serious problem on much of the land in arid and semiarid regions.

Socio-economic constraints

People who engaged in agriculture for their livelihood are likely to be worse off in the face of climate change, due to their present marginality and vulnerability to risks as well as the limited resources and capacities to withstand global warming led crises [59,60]. Food shortages are chronic and widespread because of low productivity and a range of adverse social and economic factors; local markets for agricultural products are thin and larger markets are often difficult to access [26]. Thus most households are severely constrained by the small size of their income and capital assets.

Management options

Various research have conducted across arid and semi-arid regions to enhancing production, income and livelihood; minimizing risk associated with farming in arid and semi-arid regions; utilizing and conserving the resources; and enhance mitigation and adaptation to climate change [2]. Farmers also adapted various management options to overcome negative impact of drought in dry regions. These management options varied depends up on their socio economic capability [61], availability of water resources [62], the development and availability of irrigation and other infrastructure and knowledge dissemination [63].

Soil and water conservation

A large number of studies are calling to focus efforts in enhancing soil and water conservation, soil productivities, rain water harvesting, collection and storage for beneficially uses. Rain water harvesting is an important task to increase agricultural productivity as it provides water in drought prone areas, for supplementary irrigation when rains stop early [64]. Rain water can be harvested during raining time in means of collecting and conserving surface runoff. It includes subsurface water harvesting, run-off harvesting, flood water harvesting in-situ water harvesting and roof water harvesting [65]. In situ water harvesting techniques are useful for reducing soil erosion and nutrient losses from farmland so that the combined use of tied ridges and straw mulch was the best in situ water

harvesting techniques for reducing soil loss from farmland with coarse-textured soils and gentle slopes [14].

In Sub Saharan Africa where rainfall is low, unpredictable and also expected to decline due to climate change, rainwater storage in farm ponds, water pans, subsurface dams, and earth dams could be used to satisfy water demands as a supplement irrigation during dry spells and to create opportunities for multiple uses [37,66]. For example, well-constructed check dam is most effective soil and water conserving method particularly for controlling gully and rills erosion, it is also used to collecting water that is usually used for small scale irrigation as well as planting permanent trees in the side of the check dams [67]. Similarly stone bunds contribute to agricultural productivity due to its moisture conserving role in dry areas [68,69]. Crop yield improvement was repeatedly reported especially after two to five years of the soil and water conservation structure and frequently in low rain fall areas [69]. Various soil and water conservation physical structures have great role in rehabilitating degraded land and protecting of environment against degradation, and finally improve land productivity (Figure 2) [70].

It is increasingly expressed that application of organic matter from differ sources has maintained soil productivity. However, without soil and water conservation structures, applying organic matter on highly eroded sloppy landscape cannot bring significant change. soil and water conservation structures should be installed on steep slopes before applying organic wastes; not doing so will result in all the potential soil

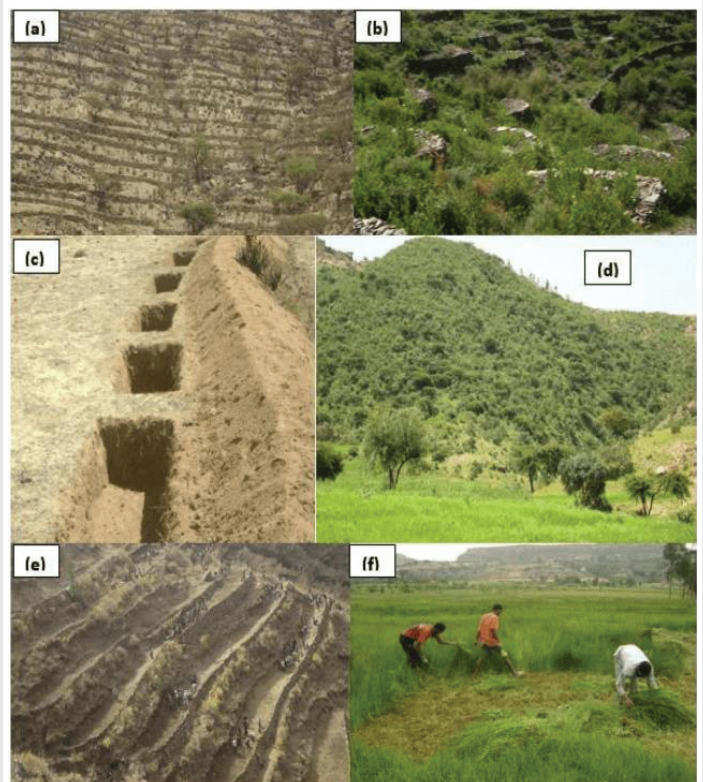


Figure 2: Commonly implemented soil and water conservation measures in Tigray: (a) Hillside terraces in a steep slope, (b) semi-circle terraces in enclosures, (c) deep trench for harvesting water, (d) enclosure in degraded steep slopes, (e) bench terraces and (f) animal feed through a cut-and-carry system after enclosures [70].

carbon gain being washed downhill [71]. Similarly the carbon density in the soil was improved through appropriate land management practices that achieve conservation of nutrients and planting of trees (Figure 3) which helps to sequester carbon and recycle it into the soil through decomposition of leaves and other plant residues [72].

Conservation tillage and mulching

Tillage and mulching have also great impact on soil physical properties and water use efficiency, particularly in dry regions. Excessive tillage compromises soil quality by causing severe water shortages that can lead to crop failure [73,74] reported that no-till with straw cover, conventional tillage with plastic mulch, and no-till with plastic mulch are suitable tillage practices for the sustainable intensification of wheat production in semi-arid areas. Similarly minimum or no tillage with straw mulching was found to increase the concentration of important nutrient (especially available P, available K and OM) in topsoil, water use efficiency and grain yield in wheat, maize and rotation annual crops [73]. Conservation tillage is considered to be an effective way of conserving soil and water and promoting the sustainable use of farmland.

Mulches are used primarily to increase water infiltration, reduce evaporation, modify soil temperatures, control weeds, prevent evaporation, increase biological activities in the soil, modify the level of available nutrients, increase the level of soil organic matter and ultimately resulted increase in crop yields [75]. Mulching enhances the formation of thin air dry layer on the top bare soil, which hampers capillary rise and slows the evaporation process [53]. Straw mulch significantly increased maize grain yield and biomass, substantiating the role of straw mulch in improving in situ water harvesting for combating soil moisture deficiency during dry periods [14]. The use of straw mulch as an in situ water harvesting techniques would further help in the long term to mitigate nutrient losses from the soil due to the release of nutrients from the straw [14].

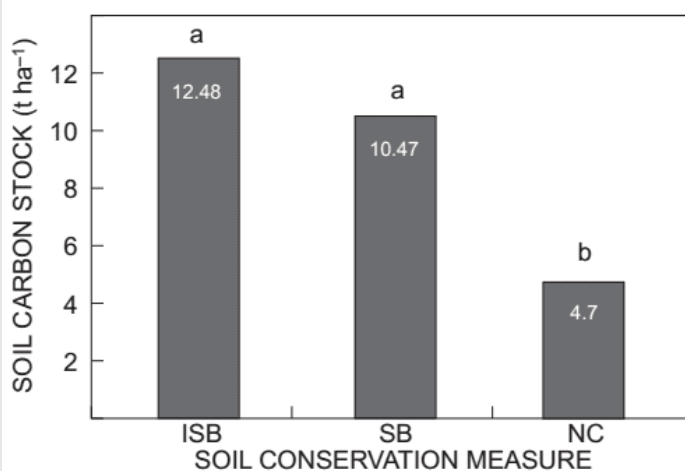


Figure 3: Soil carbon stock under the different soil and water conservation measures. Different letters above the bars indicate a significant difference at the 5% significance level. ISB = soil bunds integrated with forage species, SB = soil bunds alone, NC = non-conserved land.

Irrigation

Irrigation plays a fundamental role in crop production and agricultural development in many arid and semi-arid regions [76]. The amount of rainfall in the arid and semi-arid areas is not enough to ensure sustainable agricultural production unless supplementary irrigation or other management practices have incorporated [28]. Higher air temperatures and less precipitation, together with increasing limitations in the available water resources in semi-arid agricultural areas, led to the adoption of alternative irrigation strategies such as deficit irrigation [77,78]. Recycling wastewater for agricultural irrigation is one of the common practices in arid and semi-arid regions [79]. Insufficient water supply at the grain filling stage can lead to early leaf senescence and reduced LAI and grain yield, unless the water defect fill up with supplemental irrigation [80]. Irrigation changes widely crop responses to the environment. Application of supplementary irrigation in area where the rain fall is early cessed helps the crop to cope terminal drought. Similarly developing appropriate Soil and water conservation through mulching and various conservative soil structures can minimize negative impact of long dry spell at vegetative stage. Matching crop water demand with season supply of irrigation water will enable crops to escape terminal water stress [81]. Irrigation is a key intervention that determines the extent of loss suffered by farmers during low rainfall, delayed rainfall or drought years [19].

Although, water resources play an important role in agricultural productions and economy development, population growth and economic development have intensified the contradiction between decreasing water supply and increasing water demands particularly in arid and semi arid regions where the rainfall is scarce. The shortage of water resources has become a serious constraint to the further development of social economy [82,83]. Considering the uncertainties in agricultural system and spatiotemporal variability in evapo-transpiration and precipitation, several models were developed for optimal allocation of limited irrigation water resources [82-85].

Use of drought tolerant crop

The choice of crops or cultivars to be grown in an area must be considered environmental and economic factors. Environmental considerations include rainfall amounts and distribution, temperature, evaporative demand, soil types, pests, and proximity of cultivated areas to non-cultivated lands while productivity of cultivar, personal needs of the farmer, available markets and available of seeds are important economic considerations [86]. Under drought condition, selection of genotypes that can escape, avoid or tolerate drought condition, and appropriate agronomic management such as planting date is vital for crop production [19,78]. Low and erratic rainfall and high atmospheric evaporative demand coupled with poor water holding capacity of light soil in arid regions limits the crop growing period up to 90 days [2].

Many studies have carried out to increase plant tolerance for drought stress. Beneficial microorganisms isolated from

soils of arid and semiarid regions can help host plants to cope against drought stress [87-89]. Inoculation of plant growth promoting such as effective *Azotobacter* strains collected from semi-arid regions enhanced maize growth, through increased shoot dry weight, plant height, chlorophyll content, nitrogen, phosphorous and iron concentration under drought stress condition [88,89]. Screening of early maturing cultivars is one of the main objectives of breeding program in arid regions. However, many householders in arid and semi-arid lands are unable to test new adaptation practices such as new crop and drought-tolerant varieties due to their low capacity to invest, lack of inputs and limited access to information [90].

Cropping pattern and crop diversification

Changing cropping patterns and crop diversification is the common practices in dry land area due to high climate risk [19,91]. Some of the benefits of diversity are routinely achieved in commercial agriculture by temporal diversity (e.g., crop rotations and relay cropping) or by spatial diversity (e.g., trap crops, companion crops, and strip crops) [92]. There is also Shift from high water intensive (high income yielding such as ground nut, vegetables and) to less water intensive (low income yielding such as maize and horse gram) crops to overcome drought risk [19]. Under mixed cropping system, even one crop fail due to moisture stress, or pest infestation, additional crops grown could survive and provide economic returns [19]. In addition mixed cropping helped to meet the house hold food requirement and fodder need for cattle.

Intercropping has several benefits to the farmer including a reduction in farm inputs, diversification of diet, addition of cash crops, increased labor utilization efficiency, and reduced risk of crop failure [93,94] reported that cereal-legume intercropping could strengthen the resilience of the dry land farming community to climate change and also improve their productivity in terms of diverse harvestable food and feeds per unit area. These authors further elaborate that Intercropping also proved more superior to sole cropping in terms of farm land equivalent ratio, monetary advantage index and returns per investment. For example growing chick pea, lentil or pea before wheat, providing soil N benefit and improve soil quality, resulted in consistently higher wheat yields than wheat monoculture [95]. Similarly [96] indicated that oil seeds-legume intercropping with appropriate management is a viable option for sustainable crop production and soil fertility management in limited moisture conditions, because of better land use efficiency and better economics than the pure stand of both the crops.

Crop rotation is another important agricultural system to maintain field productivity. It refers to the sequence of crops grown in a specific field, including cash crops, cover crops and green manures. When two crops have rotation benefits growing a crop on rotated farmland is more profitable than growing it on non-rotated farmland [97] The positive impact of Crop rotation on improving of soil fertility and crop productivity is due to several reasons some of these reason include: Plants that fix nitrogen (legumes) improve soil quality for future plants planted in the same bed; Alternating shallow-rooted and deep-

rooted plants in a given area draws nutrients from the soil at varying depths; Soil borne pests that feed on one family of plants are hindered because their food source is not in the same location every year; farmers who practice crop rotation do not need to let fields lie fallow as often as they might otherwise.

Crop rotation can improve the profitability and sustainability of crop production, compared with continuous winter cereal cropping, in the semi-arid subtropical environment by optimizing crop water use, nutrient N use and market prices, and reducing adverse effects of plant disease [98].

Planting cover crops before or between main crops as well as between trees or shrubs of plantation crops can also improve soil physical, chemical, and biological properties and consequently lead to improved soil health and yield of principal crops [99].

Cover crops are crops of a specific plant those are grown primarily for the benefit of the soil rather than the crop yield. These plants are grown to improve soil fertility, prevent soil erosion, enrichment and protection of soil, and enhance nutrient and water availability, and quality of soil [100].

Livestock production

The arid area of the globe is home for extensive livestock production mainly small ruminants, Sheep and goats are the main economic output under smallholder production systems [33]. In the arid areas of the Near East and North Africa, as well as on the land that is too steep or shallow or stony for cultivation in the semi-arid fringes of these areas, the sole traditional form of land use is grazing for livestock production [101]. The distribution of small ruminants shows a concentration of animals in small scale households, where sheep and goats play a crucial role in the financial security of the poor families through sales of animals, milk or wool [33]. The small ruminant rearing has a great promise as source of income and employment and livelihood security of resource poor rural people particularly in the arid and semiarid regions [102].

The stubble of cultivated crops also provides a welcome addition to the grazing areas in summer, when natural grazing has completely dried out [101]. Sheep and goats predominate through the region; in the deserts there are also numerous camel flocks, whilst a small, hardy breed of dual-purpose cattle range the foothills and graze the stubble of cultivated crops and the spontaneous vegetation on fallow land in the areas of higher rainfall [101].

Integrated farming system

There is no single agricultural system to sustainably feeding increasing population in the world. Integrated farming system approach has been widely recognized and advocated as one of tool to harmonize use of inputs and their compounded responses to make the production system sustainable [103]. Integrated farming system, defined as an agricultural production system with multiple crops and enterprises that interact in space and/or time on a single farm has contributed

great role in ensuring food and nutritional security, providing social and economic stability, and building and protecting the ecosystem services [2]. It is a common practice in developing countries where farmland acreage and access to manufactured fertilizers and agrochemicals are limited [104]. Several studies conducted in different parts of country have revealed that an integrated farming system approach besides increasing system productivity also envisages harnessing complementarities and synergies among different agricultural sub-systems/enterprises and augments the total productivity, profitability, sustainability and gainful employment for a household [103]. For example, [105] reported that the combination of soil moisture conservation, fertilizer input application and cropping systems resulted in increasing maize yield and yield components in arid and semi-arid lands. Agro-forestry systems that incorporate the cultivation of trees, often in combination with subsistence or cash crops as well as livestock, in the dry zones of Latin America have significant potential to support livelihood resilience in areas that are considered to be highly marginalized, through contributions to economic well-being and environmental sustainability [106]. Additional income obtained from agro-forestry helped to cope with the adverse impacts of climate variability and to meet farmers' socio-economic needs and sustain their livelihoods when faced with low productivity from agricultural crops [19]. Diversified systems having the components of horticulture, fisheries, apiculture, poultry and goat are able to provide higher income compared to farming systems having two or three enterprises only, Figure 4 [107].

In general integrated farming system has multiple economic, social and environmental benefits. An emphasis in these systems is managing interactions so that waste from one component becomes an input for another component of the system, reducing the need for purchasing and applying expensive and potentially polluting inputs, such as fuel, fertilizers and pesticides, reducing leakages to the environment, and increasing overall production or income [104]. For example integrated crop-livestock systems reduce production costs due to complementarities in production such as use of grain screenings or crop residues for animal feed and subsequent application of livestock manure to land as fertilizer.

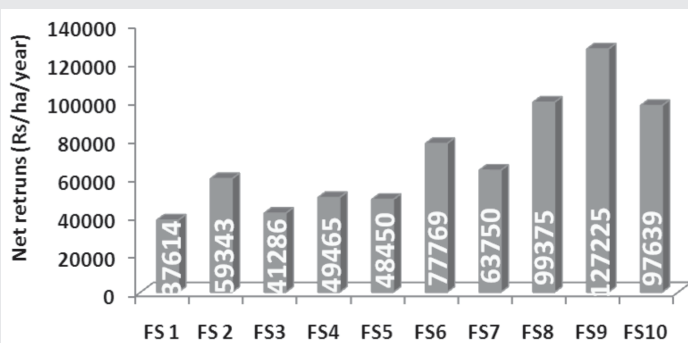


Figure 4: Monetary returns of different naturally existing farming systems in India. FS1: Crops + dairy; FS2: Crops + dairy + horticulture; FS3: Crops + dairy + poultry; FS4: Crops + dairy + goat; FS5: Crops + fishery + dairy + poultry; FS6: Crops + dairy + horticulture + poultry + fish; FS7: Rice + fish; FS8: Coconut + banana; FS9: Coconut + banana + cocoa + pineapple nutmeg; FS10: Crop + dairy + horticulture + apiary + fish.

Conclusion

A large part of the land of the world is arid and semi-arid facing with diverse constraints including prolonged dryness, low and erratic rainfall, high wind and water erosion, extreme heat and frequent drought, bared and degraded soil, and salinity problem in some low land regions. These constraints together or individually limited soil productivity in these regions. Most People who engaged in agriculture for their livelihood, in these regions, cannot be able to withstand such problems because of limited resources, low productivity and a range of adverse social and economic factors.

Thus agriculture production system in arid and semi-arid regions needs to be minimizing such problems through enhancing productivity, increasing income, minimizing risk, conserving and efficiently utilizing resources, mitigating and adapting climate change. Various agricultural system and management options have generated by different researchers and workers to overcome diverse climatic and environmental problems in these regions.

Applying appropriate soil and water conservation methods such as proper tied ridging, mulching, conservation tillage, terracing, check dam and stone bunds, appropriate for the land topography and degree of soil degradation as well as the strength of climatic risk in that specific environment have strongly recommended by many researchers to increase production and to reduce crop production constraints faced in arid and semi-arid regions.

In addition integrating of diverse farming system such as integrating livestock, agroforestry and field crops; and cropping system like crop diversification, crop rotation and use of harsh tolerant crops have huge contribution in mitigating adverse climate impact in dry regions.

Thus climatic and environmental challenges in arid and semi-arid lands can be mitigated by integrating suitable and compatible agricultural production systems and /or by applying the best alternative production system with appropriate soil and water managements.

Perspectives

- Arid and semi arid regions, with full of natural constrain, comprise most portions of the earth and farther expanding due to climate change. Mitigation of climate change and taking necessary measurements in all aspects to reduce aridity should be done to minimize risk of aridity
- The large number of population lives in arid and semi arid regions so that huge works are needed in these areas to insure the food security and wellbeing by providing several alternative technologies.
- Since the intensity, diversity and occurrence of agricultural constrain varied from location to location specific research work should be done based on specific problem, besides wide range studies.



- To overcome agricultural constraint released due to continual climate change, continual updated research work should be done to generate new technologies and mechanisms to solve the problems.
- Identification of major agricultural production constraints in the region and creating appropriate research options to solve the problem should be continual tasks
- Already adapted important practices like irrigation, various soil and water conservations, cropping pattern and crop diversification, appropriate soil and crop managements, use of harsh tolerant crops, mixed and integrated farming systems should be supported by newly research investigation and expand with large scale.

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