Effect of Agroforestry on Land Productivity in Dryland Area of Morocco

Mohamed Elkoudrim[1], Rachid Moussadek[2], Othmane El Ghalmi[3], Maryam Choukri[4]

[1,2] *National Institute for Agronomic Research, Regional Center for Agronomic Research, Settat, Morocco*

[2] *International centre of Agronomic research in dry areas (ICARDA), Rabat, Morocco*

[3] *Hassan II Agronomic and Veterinary Institute (IAV), Rabat, Morocco*

[4]*Hassan II University, Ben Msik Faculty of Sciences, Casablanca, Morocco*

Abstract:-The arid climatic context of Morocco and the extensive degradation of natural resources constitute the origin of the decline in agricultural production. The challenges generated by this situation encourage the development of innovative and sustainable technologies to maintain and secure this production. These technologies must be part not only of adaptation and mitigation of climate variations, but also of meeting needs (food, income, well-being), while conserving natural resources. In this context, agroforestry is an agricultural practice to be recommended as it can respond to many current challenges (biodiversity, diversified production, carbon storage). This work aims to characterize the performance of the agroforestry system in the semi-arid climate of western Morocco. To do this, comparisons between yields of plant and organic and mineral composition of the soil were made between agroforestry systems (SAF) and monoculture systems (MS). The introduction of shrubs and trees into agricultural plots has improved the production and quality of crops. In fact, the use of shrubs and trees in cereal fields, showed very significant differences in density, biomass and grain yield. So, agroforestry plots recorded higher values of barley biomass, with 2.75 tons/ha, 2.90 tons/ha and 3.02 tons/ha respectively for argan tree, Medicago and carob tree, than no tree plot (1.8 tons/ha). In addition, the crops yield in SAF was, in general, better than MS. On average, the barley grain production was 2.24, 1.63 and 0.65 tons/ha for carob tree, Medicago and argan tree and only 0.46 tons/ha for MS. We also found that the organic matter and total nitrogen in the soil was significantly important in SAF than in MS. In fact, the soil in barley crop for SAF contains 4.8% of OM and 3.8% for MS in top horizon (0 – 15 cm) and 4.6% and 2.6% for the horizon (15 - 30 cm). Thus, agroforestry systems are more productive and efficient and would constitute a solution for sustainable agricultural production in drylands of Morocco.

Keywords: *Agroforestry, Argan tree, Carob tree, Medicago, Atriplex, barley production, soil quality*.

1. Introduction

Agriculture plays a significant role in the Moroccan economy. National production is significantly supported by arid and semi-arid zones, where farming systems mainly integrate livestock and rainfed crops. However, agricultural production in these areas is subjected to several constraints, which lead to low productivity. In addition, the situation is worsened by the irregularity of precipitation and weather patterns. The fragility of livelihoods and ecosystems in Moroccan drylands makes the populations living there, particularly vulnerable to droughts, which are expected to increase in the future (Mrabet et al., 2012).

Cropping systems are usually poorly suited to the various agroecological zones but have been forced onto fragile environments and with a pastoral vocation due to heavy and aggressive mechanization. This situation, combined with climatic hazards, has led to a degradation of natural resources and low and unpredictable agricultural production (Gauny, 2016).

This situation calls into question conventional practices of Moroccan agriculture in arid and semi-arid areas and their potential to meet production needs in the face of serious economic and climatic challenges. Hence, we need to adopt new perspectives for the development of this sector for adaptation to droughts and restoration of natural resources (soils and vegetation), in particular Agroforestry.

In Morocco, agroforestry is particularly prevalent in mountain areas and oases, where farmers seek to maximize the profitability of their often-cramped agricultural land (Daoui, 2012). But although agroforestry is traditionally practiced in Morocco, little scientific research has focused on it (Daoui, 2012). This represents an obstacle to its evolution and expansion.

In these ecosystems, tree functions depend on size, structure, density and canopy distribution (Bora et al., 2021). Studying these parameters can provide insight into the logic by which tree species exploit resources in their canopy habitats and how this impacts the herbaceous layer. The objective of this research is to determine the effect of the introduction of trees on the productivity of the cultivated land and the protection of natural resources.

2. Material and Methods

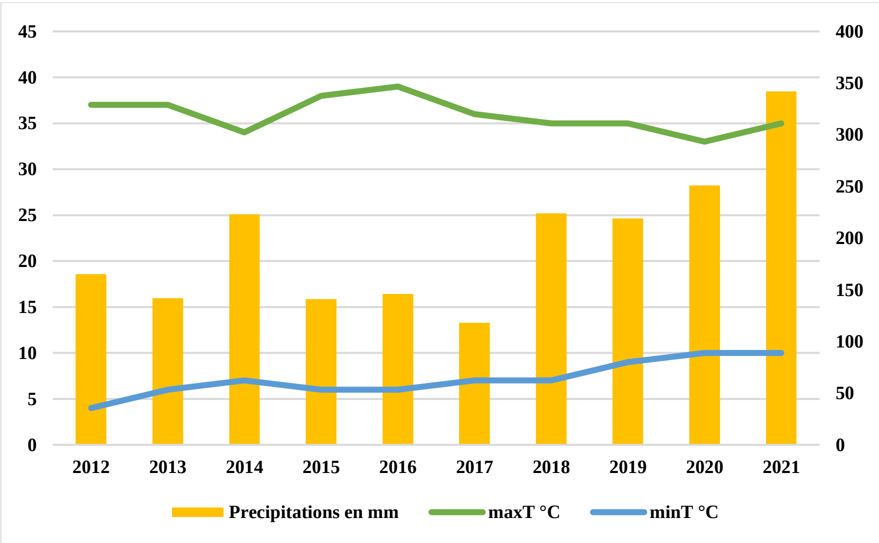

Figure 1: Average annual temperature and precipitation in the Settat region from 2012 to 2021 (Meteoblue)

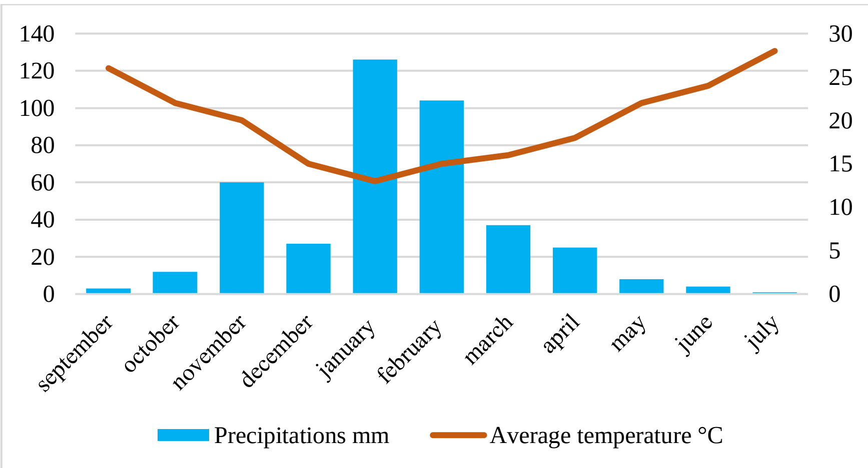

Figure 2: Average monthly temperature and precipitation in Settat during the crop year (2020/2021) (Meteoblue)

The study area is located at the experimental station of the regional agricultural research center of INRA Settat. It is considered according to the division of the major agrosystems of Morocco carried out by the Ministry of Agriculture and Marine Fisheries in 2000 as an arid to semi-arid region (Figure 2). The region is characterized by a semi-arid continental climate. Its summers are hot with temperatures oscillating between 35° and 45° and its winters are cold between 5° to 15° (El Koudrim, 2021). Precipitation fluctuates from year to year and is moderate to low (Figure 1). They are on average 350 mm during a normal year and can drop below 200 mm in a dry year (El Koudrim, 2021).

Sampling and Sample Preparation

The work presented a summary of studies carried out in experimental station of INRA Settat over the last years. It involves comparing the productivity of crops grown in a monoculture system (SM) and an agroforestry system (SAF) and the quality of the soil. The objective is to determine the effect of agroforestry on the productivity of agricultural land and soil in the arid and semi-arid regions of Morocco.

For the vegetation, the work consists of studying different parameters (density, biomass, yield). Three different plantations based on argan tree, carob tree and *Medicago arborea* are used. For each plot, samples are taken in three locations between the rows of trees: below the canopy representing maximum tree influence (shade and roots), quarter of alley with intermediate tree influence (less shade and roots) and in middle of alley marking minimal influence of trees (little shade, few roots). Samples are taken at the end of each month (January, February, March) to estimate the density and fresh weight in early stage, and number of spikes per m², number of grains per spike, weight of 1000 grains and total yield in the last sampling.

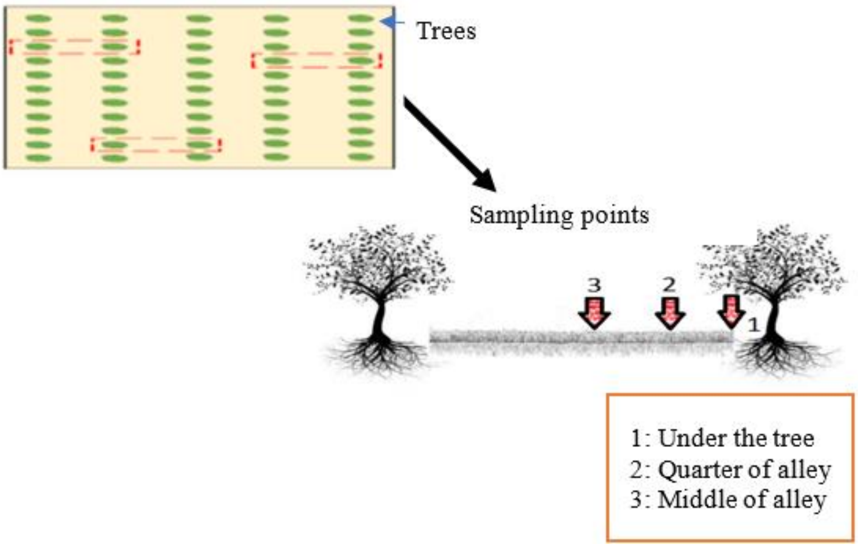

Figure 3: Experimental device

For soil, the sampling was applied with an auger at two horizons of 15 cm on two plots (Monoculture of barley and Association barley with Atriplex), 2 repetitions were taken on the diagonal of each plot for the two horizons. The samples were then air-dried, crumbled and sieved without changing their nature, thus separating the fine soil from the aggregates. Then the chemical analyses carried out in the laboratory. The determination of soil organic carbon is based on the Walkley-Black chromic acid wet oxidation method. Oxidisable matter in the soil is made by potassium dichromate. Then, we eliminated the interference of chloride that can distort the results by adding sulfuric acid, leet it set for 2 hours, and then the excess of dichromate is titrated by Mohr's salt and the soil carbon was deduced (C%= OM% / 1.724) (OM: Organic Matter).

For nitrogen analysis, we carry out the mineralization of organic nitrogen from the soil in the form of ammonium sulfate in the presence of concentrated sulfuric acid. The ammonia is released in an alkaline medium by steam entrainment and the dosage is made by acidimetry, and from the volume of HCL obtained after the dosage, the percentage of total nitrogen in the soil is calculated (N% = ((Vhcl-White) x 0.14 / PE x MS%) x 100).

Statistical Analysis

Statistical analysis was performed using SPSS statistical software as follows: Analysis of variance of means to determine if differences between means are statistically significant, at a significance level of 0.05 indicates a 5% risk. Then, a contrast test to analyse whether differences are statistically significant between specific pairs of plots containing the same crops in SAF (SAF: Agroforestry system) and MS (Monoculture System).

Table1 : Matrix of comparisons

	Monoculture system (MS)	**Agroforestry system (SAF)**
Vegetation	Barley	Barley + Argan tree Barley + Carob tree Barley + *Medicago arborea*
Soil	Barley	Barley + *Atriplex nummularia*

3. Results

Plant Parameters

Data analysis shows that plantation type present significant differences (P<0.05) for total biomass, grain yield and straw yield of barley. On the other hand, for the density of ears and their weight, and the number of grains per ear and their weight, there is a very highly significant variation (P<0.001) between plantation types.

For the position between the lines of trees and shrubs, the variation is highly (P<0.01) to very highly (P<0.001) significant for all parameters studied.

Figure 4 shows the barley grain yield comparison between SAF and MS. The Carob plot gave the highest yield in terms of barley grains, i.e. 22.4 q/ha, while the other two plots had lower yields, 16.3 q/ha for the Medicago plot, 6.5 for the argan tree and only 4.6 for MS (Table 2). The biomass is relatively similar for the plots of argan (2.75 tons/ha) and shrub alfalfa (2.9 tons/ha) and lower for MS (1,8 tons/ha). But Carob tree stands out at again with significantly higher values (3.03 tons/ha).

Furthermore, the intermediate zone (quarter of alley) has the highest density, number of grains per ear and weight of 1000 grains and therefore the highest barley grain yield, followed closely by the middle area of the plot. While the area below the trees presents lower values for all measured parameters (Figure 5). Indeed, the intermediate zone being located far enough from the trees allows the barley to benefit from the good porosity created by the tree roots without suffering from shading. This promotes more vigorous growth of the barley and improves its yield. The difference in terms of yield can be attributed largely to the density of the ears (Figure 6) which can provide information on the conditions of germination, emergence and tillering.

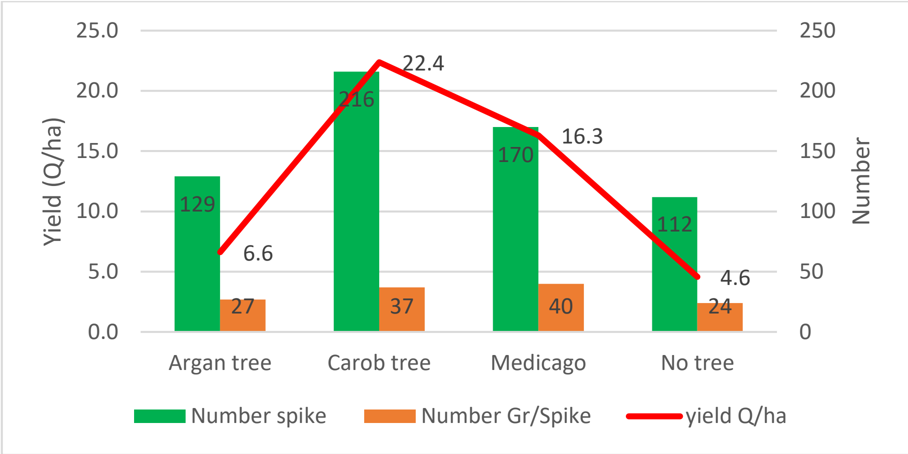

Figure 4: Comparison of SAF and MS performance

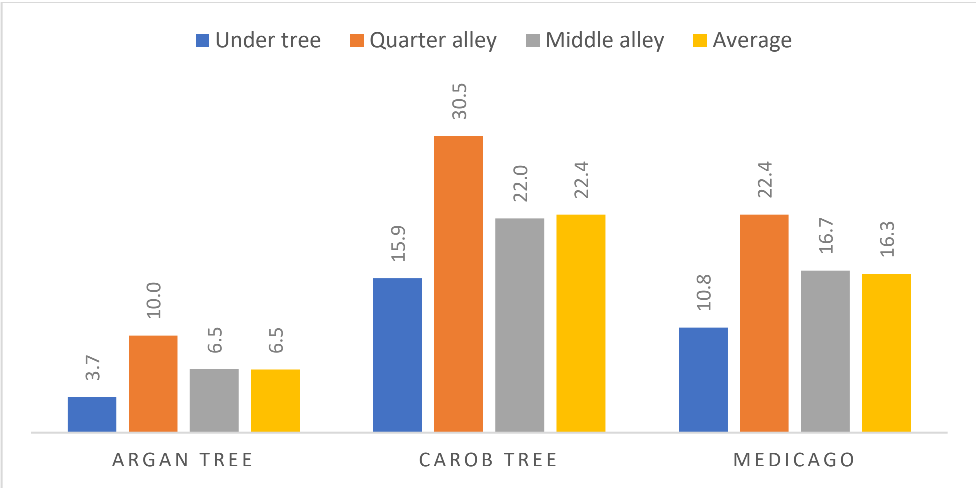

Figure 5: Grain yield depending on the distance from the tree

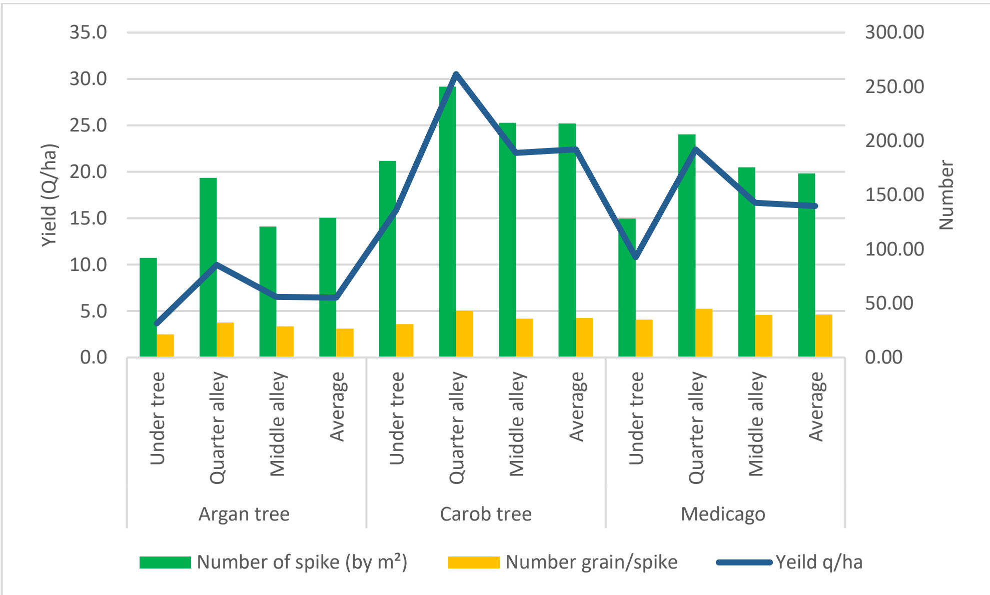

Figure 6: Barley yield parameters in different agroforestry systems

Table 2: Barley yield components for agroforestry systems and monoculture system

	Argan tree				Carob tree				Medicago				No tree
	Under tree	Quarter alley	Middle alley	Average	Under tree	Quarter alley	Middle alley	Average	Under tree	Quarter alley	Middle alley	Average	
Number of spike (by m²)	92,00	165,88	120,80	128,94	181,6	250	216,8	216,13	128,4	206	175,6	170,00	112
Number grain/spike	21,40	32,25	28,90	26,83	30,80	43,05	35,85	36,57	34,90	45,10	39,35	39,78	24
Weight of 1000 grains (g)	18,66	18,66	18,66	18,66	28,36	28,36	28,36	28,36	24,14	24,14	24,14	24,14	17
Yeild q/ha	3,7	10,0	6,5	6,5	15,9	30,5	22,0	22,4	10,8	22,4	16,7	16,3	4,6

Tableau 3: Soil quality in alley cropping and monocropping

	Horizon 1 (0 – 15 cm)				Horizon 2 (15 – 30 cm)			
	OM%	C%	N%	C/N	OM%	C%	N%	C/N
Barley	3,8	2,2	0,23	9,57	2,6	1,5	0,17	8,82
Atriplex + Barley	4,8	2,8	0,29	9,66	4,6	2,6	0,29	8,97

Soil Proprieties

The difference between soil OM (Organic Matter) and C (Carbone) at the horizon1 (0-15cm) are statistically significant between SAF and MS (P= 0.003), but the contrast test shows that the difference is not statistically significant, for barley cultivated alone and associated to *Atriplex nummularia* (P=0.803). For the horizon 2 (15-30cm) the difference is not statistically significant (P=0.155). But, on average, the soil OM and C are higher in SAF than in MS at the two horizons (Table 3).

For soil nitrogen, the analysis of variance shows a statistically significant difference between the practice of SAF and MS at both soil horizons, with (P=0.011) and (P=0.002) respectively. The contrast test shows the opposite at horizon 1, (p=0.640), whereas at horizon 2, the difference is statistically significant (P=0.020).

The analysis of variance of the C/N ratio shows that there are no statistically significant differences, and therefore the association of trees or shrubs with crops has no significant effect on the C/N ratio in the soil, the same result is obtained after the contrast test.

The introduction of trees and shrubs into croplands improves the quality of the soil. Indeed, the values of soil organic matter and carbon (C) increase in agroforestry plots based on Atriplex and barley compared to those in monoculture barley (Table 3). The OM values are 4.8% and 4,6% for the two horizons in SAF and 3,8% and 2,6% in MS. Agroforestry could therefore improve soil fertility characteristics, in particular, by improving its organic matter content. In addition, the plots under the SAF have a soil richer in nitrogen than the monoculture plots (Table 3).

The association of *Atriplex nummularia* and barley also shows an optimal C/N ratio of 9.66 in the first fifteen centimetres of the soil and 8.97 in the second, exceeding in both cases the MS (Table 3).

4. Discussion

Generally, trees enhance the density of understory vegetation relative to surrounding open areas. Thus, the density is higher between the middle of the alley and the trees because the crop benefit from the good porosity created by the tree roots and also by the light and they are less affected by competition. So, the effect of the introduction of trees and shrubs is remarkable, by the mitigation of the effect of drought on the productivity of the land in this region, result consolidated by Amenas (2008), who found that *Atriplex nummularia* has a strong capacity of water valorisation and its use with efficiency under conditions of water stress. Thus, as the density is not only a sign of the amount of vegetation produced in the plot, but also of the abundance of the crop in compared to weeds, the existence of tree and shrub showed a mitigating effect of weeds. Moreover, the weed flora is lower, most of which are annuals that complete their vegetative cycle in parallel to the barley biological cycle. This result is similar to what was found by Izquierdo et al, (2003), El Koudrim (2019), and Mézière and al (2015) to determine what impact does agroforestry associating field crops and trees have on weed communities, they showed that weed density is lower and has a different specific composition in SAF compared to MS.

For the biomass, the results are opposite to those obtained by Eddaoui (2018), who found that the biomass on the SAF is lower than in MS, due to the limiting climatic conditions combined with the competition between crop and woody plants. Indeed, the biomass of the MS plot is very low compared to the SAF plots. Thus, the biomass of MS is 1,8 tons/ha that is very low than SAF plots; argan tree (2.75 tons/ha), shrub alfalfa (2.9 tons/ha) and Carob tree (3.03 tons/ha). Overall, the Carob plot seems to offer the best yields, particularly with regard to barley grain production.

Generally, all these results show the effectiveness of agroforestry practice in semi-arid regions. And despite the negative results observed in terms of yield (Daoui et al. 2021) mainly caused by the loss of cultivated area and by the pressure of competition from trees on crops, particularly in unfavorable climatic conditions, the overall profitability of the agroforestry system reaches its optimum once the trees come into production, similarly trees increase the value of land capital from year to year (Gagnon, 2015). In our case *Atriplex nummularia*, as cited by Amenas (2008), can produce 10-20 kg of DM/mm of rain per year. In arid and semi-arid areas, Atriplex was associated in the alley cropping system with barley, oats or alfalfa, it played an important role as a windbreak, protection of soils and creating a favorable microclimate, allowing other forage species to establish themselves and increase their productivity (Chriyaa and El Mzouria., 2004). Furthermore, El Koudrim and al. (2020) proved that *Atriplex nummularia* can provide additional very good quality fodder estimated at more than 400 kg DM/ha and could reach 550 kg DM/ha, with a greater quantity of firewood. This fodder would be added to that produced by intercropping forage and would provide the element most lacking in dryland fodder resources, namely nitrogen or total nitrogenous matter.

Furthermore, tree alfalfa (Medicago arborea), a spontaneous shrub from the Mediterranean Basin particularly rich in protein (De Koning and Duncan, 2000), constitutes another agroforestry alternative fodder shrub for the Moroccan arid zones. The introduction of this shrub in association with barley or forage species reduces the impact of periods of scarcity by improving forage availability (El Koudrim and al., 2020). In fact, Medicago arborea produces significant and good quality aerial biomass. This fodder is added to that produced by intercropping fodder crops and provides the element most lacking in fodder resources in arid zones, namely nitrogen or total nitrogenous materials (TAM). Hamdi et al. (2019) reported MAT levels of 14.4% and Ventura et al. (1999) found values of 15.5%. On the other hand, Medicago arborea has a relatively high level of mineral matter and low levels of wall constituents (Hamdi et al. 2019, Ventura et al. 1999).

In conclusion, in addition to the ecological interest of woody plants, agroforestry plots present economic profitability. It allows both to maintain an annual income thanks to intercropping, and to build up valuable capital, with trees. The optimal density of adult trees in the arid area is between 50 and 100 trees/ha depending on the species and the fertility of the plots (Dupraz et al., 2005). Agroforestry also makes it possible to diversify agricultural income through the production of wood and non-wood forest products (De Baets, 2007).

Soil Proprieties

The soil in the region is generally shallow and poor in organic matter, two characteristics that prevent the storage of water in the soil and consequently aims to limited water reserve.

Indeed, the analyses of organic matter have shown positive results in this regard. Even though, the results obtained for barley associated to Atriplex nummularia and barley alone, which can serve as an example for all semi-arid regions in Morocco since barley is one of the crops most practiced by farmers. Indeed, the SAF showed higher organic matter and carbon proportions than the MS for both soil horizons. A study conducted in 2014 in the semi-arid zones in Morocco found that 70% of the soils are poor in organic matter and contain from 0.7 to 1.5% OM (El Oumlouki, et al., 2014), while we have proportions revolving around 4.5% at the first horizon and 4.7% at the second in agroforestry, thanks to the introduction of *Atriplex nummularia* which is characterized by an improving effect of the characteristics of soil fertility, its moisture and its organic matter (Brinis, 2016).

Additionally, the combination of trees and crops in the same plot showed that SAF practice contained more soil nitrogen than plots under MS at both soil horizons. This proves that trees can provide nitrogen inputs in agroforestry systems either through biological nitrogen fixation (BNF) or through deep nutrient uptake (Sanchez and Palm, 1996). Which shows great interest for farmers in semi-arid regions of Morocco, who face problems of nitrogen starvation for cereal crops, which is why the introduction of trees, can be a natural remedy and cost-effective in itself to combat this problem. These are proven by Young (1995) who found that it would be very beneficial to practice agroforestry by combining shrubs and crops in the same plot, and found that in a semi-arid climate, the soil fixes 1, 5 to 3 times more nitrogen under trees than without them, so using nitrogen-fixing woody plants can reduce root competition with crops. The fact that the woody plant partially meets its requirements through fixation reduces soil depletion around its roots and makes more nitrogen available to non-nitrogen-fixing associates (Gillespie et al., 2000).

On the other hand, the C/N ratio was optimal for the SAF with values of 9.68 at the first horizon and 9.36 at the second horizon, values which allow good microbial activity and a good balance between humification and mineralization, this is due to the balance created by the presence of the shrub, which both offers organic matter and nitrogen to the soil.

However, high C/N ratios mean that mineralization is slow and consequently the stock of humus incorporated into the soil is high, so nutrients are less available to plants (Genot et al., 2012).

In summary, agroforestry constitutes an important provider of goods and services for the environment, falling within a context of integrated management of agricultural land and rural areas (De Baets, 2007).

5. Conclusion and Recommandations

In conclusion, planting trees brings several benefits to producers, for example increased yields, diversification of products and activities, as well as income and social development, and subsequently the enhancement of heritage for future generations. In addition, the SAF system offers better product quality (fodder, cereals) thanks to high proportions of nitrogen and TNM in the plant material, as well as the additional fodder contained in the leaves of trees and shrubs or other products . Likewise, the SAF system offers better use of soil and water resources in arid and semi-arid zones, thanks to the characteristics of the species used and the better organic and mineral quality of the soil and its fixation, which gives it makes it possible to resist droughts and desertification and to better store water.

From an economic and social point of view, SAF makes it possible to both maintain an annual income thanks to intercropping and to constitute valuable capital, with the trees.

The different sections presented in this study highlight the effects of agroforestry on land productivity in the semi-arid regions of Morocco, how to benefit from this practice, and compensate for the losses that can result from the competition of trees with crops. To this end, we propose the following recommendations:

- Adopt agroforestry practices and plant trees in the rows and borders of agricultural plots to ensure a constant supply of organic matter and mineral elements, while limiting the risks of erosion and facilitating water infiltration; .
- Optimize grazing and rediscover and diversify local plant species better adapted to the territory, notably shrub and tree species to ensure a balance between the capacity of the soil to produce forage resources and the food needs of the herds,

- Carry out research on associations (trees, crops) to find the most appropriate and relevant. Focus on the processes and conditions necessary to widespread their adoption, in order to solve the problems of Moroccan arid and semi-arid zones, and thus guarantee the sustainability of agriculture for future generations.
- The social commitment of the State in the organization of awareness and training campaigns for farmers, and financial to provide subsidies and aid to encourage the adoption of agroforestry.

Remember that there are always good years and bad years, and bad years are likely to repeat more frequently with climate change. It is important to prepare and adapt by putting in place good practices which secure the agricultural system.

References

[1] Chriyaa Abdelouahid, A., & El-Mzouri, H. (2004). Introduction of fodder shrubs in low rainfall areas of Morocco. Cahiers Options Méditerranéennes (CIHEAM).

[2] Daoui K., 2012, L'agroforesterie ou l'art de combiner des arbres et des cultures, INRA Meknès Magazine, Publié le 17 avril 2014, par, Bahri N

[3] Daoui K., M. Fatemi, R. Razouk, A. Bouaziz, Barkkaoui et A. Amassghrou (2021). Optimisation de la production des systèmes agroforestiers : olivier – céréales – légumineuses. Rapport d'activité PRMT 2021-2024. INRA, Maroc

[4] De Baets, N. (2007). Le portrait de l'agroforesterie au Québec. Agriculture et agroalimentaire Canada.

[5] Dupraz & C. Alain , 2005, L'agroforesterie : une voie de diversification écologique de l'agriculture européenne, page 1.

[6] EDDAOUI Mohammed, 2018, L'amélioration de la production fourragère dans les zones semi-arides cas : la région de Chaouia (rapport de master, Université HassanII, faculté des Sciences et techniques de Settat, département de Biologie)

[7] El Oumlouki et al., 2014 in Benazzouz, I., Talbi, M., & Saber, N. Etat Environnemental Des Sols De La Region De Casablanca.

[8] Gagnon, L. M. (2015). Performance des fourrages en système de culture intercalaire au Québec.

[9] Genot, V., Renneson, M., Colinet, G., Goffaux, M. J., Cugnon, T., Toussaint, B., ... & Oger, R. (2012). Base de données sols de REQUASUD-3ème synthèse.

[10] Izquierdo i Figarola, J., Recasens i Guinjuan, J., Fernández-Quintanilla, C., & Gill, G. (2003). Effects of crop and weed densities on the interactions between barley and Lolium rigidum in several Mediterranean locations. Agronomie, 2003, vol. 23, núm. 7, p. 529-536.

[11] El koudrim M., 2021, Contribution à la gestion de l'intégration de l'agriculture et de l'élevage en milieu aride et semi-aride sous le système d'agriculture de conservation (dissertation doctorale, Université Hassan 1er de Settat, Maroc)

[12] El Koudrim M., Laamari A., Acherkouk M., Chriyaa A., El Mzouri E. and Hilali S., 2020. Participatory evaluation of the degradation of El Hadra rangeland (Rhamna Province). African & Mediterranean Agricultural Journal (AFRIMED – AJ) Al Awamia (128). p. 62-75.

[13] El koudrim M., Ouabbou H. et El Hilali S., 2019. Evolution and transformation dynamics of rangeland in Moroccan north Atlasic plains and plateaux: Rhamna's case. 1st Joint Meeting, FAO-CIHEAM Networks on Sheep and Goats and on Mediterranean Pastures.1ére Réunion Conjointe des Réseaux FAO-CIHEAM sur les Ovins et les Caprins et sur les Pâturages méditerranéens. Meknès, Maroc, 23-25 Oct 2019.

[14] Mézière, D., Colbach, N., Dessaint, F., & Granger, S. (2015). Which cropping systems to reconcile weed-related biodiversity and crop production in arable crops? An approach with simulation-based indicators. European Journal of Agronomy, 68, 22-37.

[15] Gillespie R., S. Jose, D. B. Mengel, W. L. Hoover, P. E. Pope, J. R. Seifert, D. J. Biehle, T. Stall and T. J. Benjamin. (2000). Defining competition vectors in a temperate alley cropping system in the midwestern USA: 2. Competition for water. Agroforestry systems, 48(1), 41-59

[16] Sanchez, P. A., & Palm, C. A. (1996). Recyclage des éléments nutritifs et agroforesterie en Afrique. Unasylva, 185(47), 12-16.

[17] Young, A. (1995). L'agroforesterie pour la conservation du sol

[18] Mrabet, R., Moussadek, R., Fadlaoui, A., Van Ranst, E., 2012. Conservation agriculture in dry areas of Morocco. Field Crops Research 132, 84-94

[19] Gauny J., 2016. Crop residues tradeoffs in rain-fed areas of Morocco. MSc Thesis Report. Wageningen University, Netherlands.

[20] Bora, Z., Angassa, A., Wang, Y., Xu, X., You, Y., 2021. Effect of elevation on the density and species composition of encroacher woody plants in Borana rangeland, southern Ethiopia. Environ. Manag. 1–13.

[21] Meteoblue : https://www.meteoblue.com/fr/meteo/semaine/settat_maroc_2537406

[22] Amenas Y., 2007, Caractérisation de la réponse physiologique d’Atriplex halimus et Atriplex canescens sous l’effet du stress hydrique (doctoral dissertation, université d’Oran)

[23] De Koning C.T.and Duncan A.J. 2000. Medicago arborea - a leguminous fodder shrub for low rainfall farming systems. In Sulas L. (ed.). Legumes for Mediterranean forage crops, pastures and alternative uses. Zaragoza: CIHEAM-IAMZ, 2000. p. 435-438: (Cahiers Options Méditerranéennes: v. 45).

[24] Hamdi H., Majdoub-Mathlouthi L., Kraiem K. (2019). Caractéristiques floristiques d'un parcours naturel amélioré par le Medicago Arborea dans le semi-aride de la Tunisie. Université de Sousse, Institut Supérieur Agronomique, BP 47, 4042 Chott-Mariem, Sousse, Tunisie.

[25] Ventura M.R., Flores M.P., Castañón J.I.R. (1999). Nutritive value of forage shrubs: Bituminaria bituminosa, Acacia salicina and Medicago arborea in Etienne M. (ed.). Dynamics and sustainability of Mediterranean pastoral systems Zaragoza : CIHEAM Cahiers Options Méditerranéennes; n. 39 p 171-173.

[26] Brinis Amir (2016), Etude de la variabilité génomique des trois espèces d’Atriplex (halimus, nummularia, canescens) et sélection de caractères de tolérance au stress salin (doctoral dissertation, université d’Oran).