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Feasibility of ley-farming system performance in a semi-arid region using spatial analysis

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ABSTRACT

In order to assess feasibility of ley farming system performance in the Aq-Qala township, a semi-arid region in north of Iran, Multi-Criteria Analysis (MCA) method and Geographic Information System (GIS) techniques were integrated to evaluate the suitability of wheat, barley and annual alfalfa cultivation. The agronomic and ecological requirements of three crops were identified from available scientific literatures. In this study, environmental variables were included: 1) average, minimum and maximum temperatures, 2) precipitation, 3) slope, 4) slope aspects, 5) elevation and 6) soil characteristics such as organic matter, pH, electrical conductivity (EC), texture, nitrogen, phosphorus, potassium, calcium, iron, and zinc. Weights of these variables were extracted from analysis of Analytical Hierarchy Process (AHP) questionnaires. The suitability analysis was based on matching between land qualities/characteristics and crop requirements. It was done by the weighted overlay technique (WOT) in GIS. In order to assess the land suitability of ley farming system performance, the digital suitability layers of three crops were overlaid and integrated in GIS media by raster calculator functions, then zoning of region was done in 4 classes, including: Highly suitable, moderately suitable, marginally suitable and non-suitable. Our results indicated that 35.1% (35495.20 ha) of total areas of studied region is suitable for ley farming system. According to the generated agricultural suitability map, it was determinate that 15.2% (20681.77 ha) of the region is non-suitable for ley-farming performance, 19.5% (23245.74 ha) is marginally suitable and, 30.2% (33725.60 ha) is moderately suitable. Highly suitable, moderately suitable and marginally suitable lands were expected to have a crop yield of 80–100%, 60–80% and 40–60% of the yield under optimal conditions with practicable and economic inputs, respectively. It was found that the most areas of the southern and central parts of Aq-Qala are the highly and moderately suitable regions. The results demonstrated that the high EC, low OM and low rainfall are the key limiting factors in non-suitable areas.

1. Introduction

The term “ley” is derived from the old-English “lea” which means a grassy fallow vegetation on former crop fields (Glatzle, 1988). It refers to a land use system where arable crops alternate with vegetation used for livestock production. Accordingly, spontaneous fallow vegetation that is grazed by livestock prior to cropping, is an “unregulated” ley system as defined by Ruthenberg (1976). In the mid 1930’s self-regenerating annual legume pastures were adopted into southern Australian cereal farming systems. The use of subterranean clover (*Trifolium subterraneum* L.) and various alfalfa (*Medicago* spp.) species, together with applications of superphosphate, improved soil fertility and led to increased cereal yields and greater sheep and cattle production (Puckridge and French, 1983). The ability of tillage systems to maintain sufficient alfalfa seed reserves (200 kg ha^{-1}) in the topsoil (0–50 mm) without decreasing the yields of the successive wheat (*Triticum aestivum* L.) crop is one of the major factors determining the success of alfalfa in ley farming systems with wheat (Kotzé et al., 1998).

The value of legumes as nutritious food and forage crops and for soil rehabilitation has been recognized for thousands of years, but the use of self-regenerating annual species of *Trifolium* and *Medicago* in rotations with cereal crops is an especially southern Australian development (Puckridge and French, 1983). The “ley” systems are widely used in countries such as Australia, Brazil,

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Colombia, Argentina, with positive results (Hohnwald et al., 2000; Ovalles et al., 2004). This alternation derives in multiple benefits such as a more profitable grain production, better forage quality for livestock, self regeneration of legume pastures, decreased use of inorganic fertilizers, improving soil quality and an overall benefit by increased carbon fixation (Hohnwald et al., 2000; Navas et al., 2011).

Legume characteristics that are particularly relevant for ley systems are as follows: 1. ease of establishment (high seed production potential), 2. ease of re-establishment, 3. high nitrogen fixation (a function of plant productivity and soil adaptation), 4. ease of control during the crop phase, 5. tolerance to drought, diseases and pests, 6. high animal production (Schultze-Kraft, 1995).

The effect of six methods of tillage commonly used in alfalfa and cereal farming in the southern Cape (South Africa), on the distribution of the alfalfa seed reserves in the soil profile and yields of successive wheat crops was investigated by Kotzé et al. (1998). Results revealed that tine implements, regardless of the depth of cultivation, maintained more seed in the topsoil, compared to the shallow-disc, deep- disc and moldboard ploughing. Also, seed reserves in the topsoil correlated with the regeneration and growth of the following alfalfa pastures. In study, Albizua et al. (2015) used data from four long-term (55 years) agricultural experiments in southern Sweden to assess the effects of two arable farming systems on a range of indicators of soil ecosystem services. One farming system used only annual commodity crops (ACC system) while the other integrated one year of ley (ley system) into the crop rotation. Nitrogen was applied annually in both farming systems at two rates (0 and 150 kg N ha^{-1}). The ley farming system had an addition of farmyard manure (FYM) once every fourth year. Results showed that yields of wheat were greatest in the plots that received N fertilizer, irrespective of farming system, while mycorrhizal fungal biomass was greatest in the ley system with no inorganic N fertilizer. The ley system with N fertilizer had significantly greater values of regulating and provisioning services relative to the other treatments. The results indicated that different farming systems could have large effects on ecosystem service flows, and that integrating leys into arable rotations can enhance the delivery of soil ecosystem services.

On the eastern plains of Venezuela, a study was carried out to evaluate the behavior of local forage legume species and its influence on chemical and biochemical properties of soil with the ultimate goal of identifying which one of these species had the potential to be used as cover in the establishment of a ley farming system. For this propose, a study was conducted on an Oxisol and used five local species from the genus *Centrosema* which were established as cover for a period of 3 years. The results indicated that dry matter production varied among the different legume covers, and *C. macrocarpum* had the greatest productivity (1340 kg h^{-1}). Thus, the legume crop covers influenced positively the soil quality. *C. macrocarpum* was the legume cover that showed the greatest soil improvement, having the best potential to be used as forage cover to establish a ley farming system in this region (Navas et al., 2011).

Agricultural intensification has contributed substantially to the increase in food production, but has come at the expense of soil degradation and environmental problems. Management of soil based ecosystem services needs to be considered in agricultural management since intensive management implies not only costs to the farmer but also to society (Albizua et al., 2015). It is essential to allocate crops to the most suitable land areas precisely for the best production since the arable land area has been decreasing (Zhang et al., 2015). Selecting the most appropriate algorithm for land suitability assessment is important for current and future land use planning. Several approaches have been attempted to conduct land suitability assessment. Geographic Information System (GIS) technology is useful for integration of bio-climate, terrain and soil-resource-inventory information (Sarkar, 2008). Parametric method is one of the traditional methods of land suitability assessments, in which land characteristics are matched against the crop requirement, producing suitability rating for each land characteristic (Sys et al., 1991). Also, land evaluation framework of FAO (1976) was widely used, in which land suitability for crops can be evaluated in terms of suitability ratings ranging from highly suitable to not suitable based on climatic, topographic data and soil properties (Zhang et al., 2015). Bhagat et al. (2009) analyzed and evaluated the land suitability for cereal production in Himachal Pradesh (India) using GIS. The considered different parameters such as climatic (precipitation and temperature), topographic (elevation), soil type and land cover/land use. They could discriminate suitable areas for growing these crops and proposed that the method can be harnessed efficiently for achieving long term sustainability and food security.

A key step of land suitability assessment for crop production is to determine the weight of each factor which influences the land suitability. The presence of various and multiple criteria makes land suitability assessment complicated because factors influencing land suitability have unequal levels of significances (Elsheikh et al., 2013). The integration of Multi-Criteria Analysis (MCA) methods such as Analytical Hierarchy Process (AHP) with GIS is a trend in land suitability analysis. This combination could be useful in solving conflictive situations for individual or groups interested in spatial context and is also a powerful approach to land suitability assessments (Malczewski 1999; Elsheikh et al., 2013). AHP is one of the most widely used multiple criteria decision-making tools. This technique is based on ranking and the importance of factors affecting the goal by attributing relative weights to factors with respect to comments provided in the questionnaires. Many outstanding works have been published based on AHP, among which are: applications of AHP in different fields such as planning, selecting the best alternative, resource allocations, resolving conflicts, optimization, and numerical extensions of AHP (Vaidya and Kumar, 2006). Kazemi et al. (2016) concluded that a combination of GIS and AHP is a practical and applicable method for determining land suitability for faba bean crops. An MCE approach, within a GIS environment, was used by Ceballos-Silva and López-Blanco (2003) identify suitable areas for oat crop production in Central Mexico. According to the weighting vectors, the results signified the precipitation, altitude and soil depth as the most important variables affecting the growth of oat crop. Lai et al. (2002) applied AHP in group decision making, which has proved to be more beneficial than the conventional techniques such as the Delphi techniques. The AHP method, as compared to Delphi, allows participants to evaluate and discuss tasks more comprehensively. In general, the participants are more satisfied with the AHP than with Delphi, not only in the decision process but also with the outcome of the decision.

Suitable areas for agricultural use are determined by an evaluation of the climate, soil, and relief environment components, and the understanding of local biophysical restraints. In this kind of evaluation, many variables are involved and each on should be weighted according to their relative importance on the optimal growth conditions for crops (Ceballos-Silva and López-Blanco, 2003). Many studies have focused on land suitability evaluation based on Geographic Information System (GIS) and Multi-Criteria Analysis (MCA) (Elsheikh et al., 2013; Rahman and Saha, 2008; Trong Due, 2006; Nekhay et al., 2009; Menas and Delali, 2012; Akinci et al., 2013; Abushnaf et al., 2013; Houshyar et al., 2014; Kazemi et al., 2015). However, there have been few studies which evaluate the land suitability for forage legume and ley farming system. The present study was therefore carried out with the objective land suitability analysis for feasibility of ley-farming system performance in semi-arid region using geographical information system

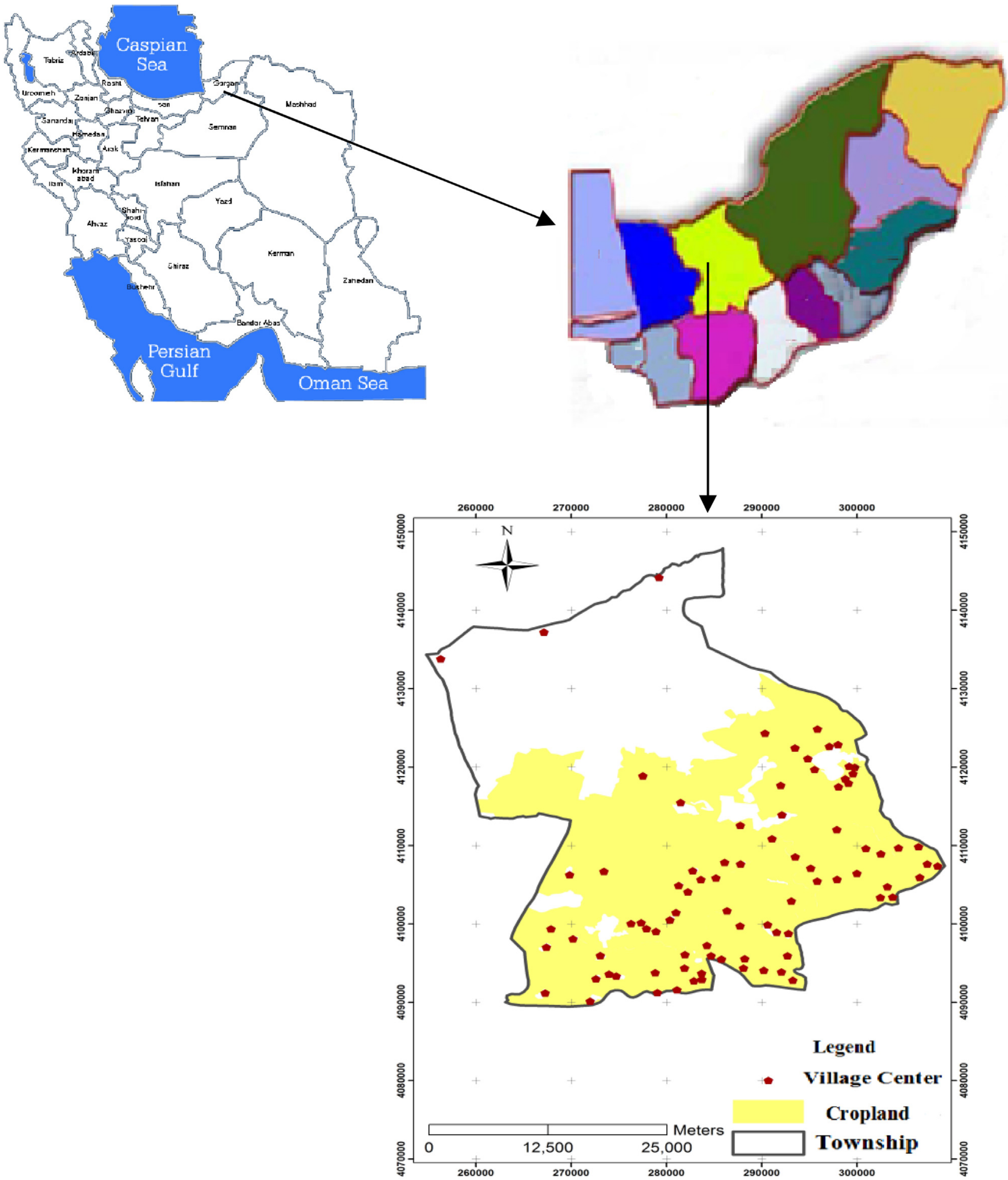

Fig. 1. Location of the study area in Aq-Qala township, Golestan province, Iran.

and evaluation of environmental variables in agricultural lands of Aq-Qala region, in north of Iran.

2. Materials and methods

2.1. Study area

One of the most important areas for crop production in Golsetan, north of Iran, is the Aq-Qala region. This area is located between latitude 54° 14.2′ N and 54° 51′ N and longitude 36° 55.3′ E and 37° 29.6′ E (Fig. 1). The total area of the Aq-Qala is approximately 1763 km^2. Most of the area is used for rainfed agriculture, such as wheat, which is the principal crop with 28,465 ha, barley (5534 ha) cotton (2693 ha), corn (1618 ha) and alfalfa (323 ha). Wheat and barley are some of the most important crops in this region. Wheat production and grow of sheep and cattle are the major sources of income for the local farmers. The climate of this region is under the influence of Alborz Mountains, Caspian Sea, and the southern wildernesses of Turkmenistan. The zone has a semi-arid climate, according to De-Martonne advanced climate classification system, with mean annual temperatures 17.86–18.34 °C and annual precipitation ranges from 249 to 529 mm. In the study area, the elevations varies from 0 to 86 m above the sea level (Golestan Province Government, 2009).

2.2. Parameters used in the suitability analysis

In order to determination of the land suitability for cultivation of wheat, barley and alfalfa, some parameters such as topography, soil, climate and land use map were used. The digital elevation model (DEM) dataset with a 40 × 40 m resolution and political boundary map with township boundary of the study area were obtained from the natural resources organization of Golestan province. Also, topographic layers such as slope, slope aspect and elevation were obtained from the DEM by surface analysis in ArcGIS 10.0 software. The soil properties data were obtained from 250 sampling sites distributed in Aq-Qala township, including organic matter, total nitrogen, available potassium, available phosphorus, EC, pH, Ca, Fe, Zn and texture. In this research, the spatial distribution of soil characteristics on the agricultural lands of Aq-Qala were evaluated using different geostatistical and interpolation methods such as, Ordinary Kriging and Inverse Distance Weighted (IDW). Meteorological data were obtained from 36 weather stations located within the study area and the surrounding zone. The data were averaged from 1995 to 2013. The rainfall and temperature data of the whole were used to interpolate and mapping of annual rainfall, annual average, maximum and minimum temperature by IDW and Ordinary Kriging methods.

Then, in ArcGIS environment, all the spatial data were converted into raster layers with 50 m resolution and georeferred to UTM (WGS-84) coordinate system. The land use map of Aq-Qala township was used to extract layers of non–planting regions, including bare lands, industrial and residential areas, water bodies and impervious lands.

2.3. Analytical hierarchy process (AHP)

In multi-criteria assessment process, one of the important steps is to determine the weight of each criteria. AHP was adequate to determine the weights of assessment factors. For this purpose, the first step is to construct an AHP hierarchical model consisting objectives, criteria, sub criteria, and alternatives. The objective was to determine the feasibility of ley-farming performance in semi-arid region, and the criteria included climate, soil and topography, each of which had 3–10 sub criteria. The sub criteria of soil were included organic matter, pH, EC, texture, nitrogen, phosphorus, potassium, calcium, iron, and zinc. Environmental variables were included as: 1) average, minimum and maximum temperatures, 2) precipitation, 3) slope, 4) slope aspects, 5) elevation. In this investigation, alternatives were considered: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and non-suitable (NS). Such structure allows the incorporation and accommodation of both qualitative and quantitative criteria to assess land use suitability. The basic step of the AHP was to assign the relative importance (or influence percentage) of factors. Within each level of the hierarchy tree, the relative importance between each pair of criteria to the objective is evaluated. A nine-point scale based on Saaty (1980) approach is used for these evaluations (Table 1). In this study, 25 agronomy experts were invited to estimate the relative importance of the factors. The final step, the weight of factors for land use suitability was obtained from local experts, through a pairwise comparisons statistical analysis in Expert Choice software (version 2000). A standardized eigenvectors was extracted from each comparison matrix. These weights assigned to each criteria and sub-criteria then the all layers overlapped. For each level in the hierarchy, it is necessary to know whether the pairwise comparison has been consistent in order to accept the results of the weighting. The parameter that is used to check this is called the Inconsistency Ratio. This ratio is a measure of low much variation is allowed and must be less than 10% (Saaty, 2000; Trong Due, 2006).

Table 1
Explanation of the standard nine-point preference scoring system used for the AHP (Saaty, 2000).

Preference score	Explanation of numerical preference score
1	Two attributes preferred equally
3	Judgment slightly favors one attribute over another
5	Judgment strongly favors one attribute over another
7	Judgment very strongly favors one attribute over another
9	Extreme preference of one attribute over another
2, 4, 6, 8	Intermediate values between the two adjacent judgments

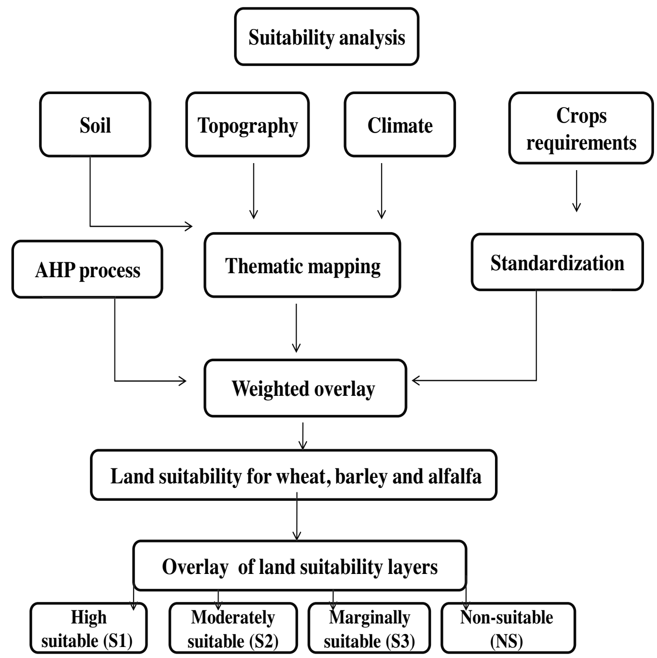

Fig. 2. Schematic diagram of land use suitability for ley farming system performance in Aq-Qala region, Iran.

2.4. Land suitability analysis for ley-farming performance

In order to assess the land suitability for ley farming performance in Aq-Qala township, were used to match the environmental requirements of crops (wheat, barley and annual alfalfa) and the some land characteristics. A schematic diagram of land suitability is shown in Fig. 2. The first step in delineating suitable areas was to identify the relevant enviromental variables. In this research, environmental requirements of three crops were identified from scientific literatures and local expert's opinion then classified (Tables 2–4) and needed thematic maps were provided.

In determining the weights of parameters, expert opinions were involved, and with the allocation of AHP weight for any criteria, land suitability was done by the weighted overlay technique (WOT) in ArcGIS. Weighted overlay is a technique for applying a common level of values to various and dissimilar input to create an integrated analysis. This system was based on matching between land qualities/characteristics and crop requirements. A Land suitability map for each crop was generated in 4 classes, including: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and non-suitable (NS). Thus S1 represents that the land unit is highly suitable

Table 2
Criteria for delineating land suitability of wheat in Aq-Qala region, Iran (Akinci et al., 2013; Bhagat et al., 2009; Ghafari et al., 2000; FAO, 1976; Kazemi et al., 2015; Menas and Delali, 2012; Sarkar, 2008; Sys et al., 1991).

Features	Highly Suitable (S1)	Suitable (S2) Moderately	Marginally Suitable (S3)	Non-Suitable (NS)
Precipitation (mm)	400≤	300–400	200–300	<200
Average temperature (°C)	16–20	12–16 and 20–24	8–12 and 24–30	<8 and >30
Minimum temperature (°C)	10–15	7–10	4–7	<4
Maximum temperature (°C)	20–25	25–30	30–37	>37
Slope (%)	0–4	4–8	8–12	>12
Slope aspects	Plateau, south and southeast	East and northeast	Southwest and northwest	West and north
Elevation (m)	< 1000	1000–2000	2000–3000	>3000
EC (dS.m^{-1})	0–4	4–8	8–12	>12
pH	6.5–7.5	5.5-6.5 and 7.5-8.5	5–5.5	<5.5
Soil texture	Loam, Clay loam, Clay, Silty clay loam	Sandy loam, Sandy clay loam	Loam sandy, Silty loam, Sandy clay, Silty clay	Sandy
Organic Mater (%)	≥3	2–3	1–2	<1
N (%)	1≤	0.7–1	0.5–0.7	0.5>
K (mg kg^{-1})	200–250	150–200 and 250–300	100–150	<100
P (mg kg^{-1})	10–12	7–10 and 12–15	5–7 and 15–18	<5 and >18
Ca (mg kg^{-1})	5–15	15–25	25–50	>50 and <5
Fe (mg kg^{-1})	10–15	15–18 and 8–10	18–20 and 5–8	<5 and >20
Zn (mg kg^{-1})	0.9–1.1	1.1–2	2–6	>6 and <0.9

Table 3
Criteria for delineating land suitability of barley in Aq-Qala region, Iran (Akinci et al., 2013; Bhagat et al., 2009; Ghafari et al., 2000; FAO, 1976; Kazemi et al., 2015; Sarkar, 2008; Sys et al., 1991).

Features	Highly Suitable (S1)	Suitable Moderately(S2)	Marginally Suitable (S3)	Non-Suitable (NS)
Precipitation (mm)	300<	200–300	150–200	<150
Average temperature (°C)	15–20	12–16 and 20–24	8–12 and 24–30	<8 and >30
Minimum temperature (°C)	10–15	7–10	4–7	<4
Maximum temperature (°C)	20–25	25–30	30–37	>37
Slope (%)	0–4	4–8	8–12	>12
Slope aspects	Plateau, south and southeast	East and northeast	Southwest and northwest	West and north
Elevation (m)	1–1000	1000–2000	2000–3000	>3000
EC (dS.m^{-1})	0–4	4–8	8–16	>16
pH	6.8–8	6-6.6 and 8-8.5	5–6	<5 and 8<
Soil texture	Clay loam, Loam, Sandy clay loam, Loamy silty, Silty clay loamy	Sandy clay, Clay, Silty clay, Sandy loamy, Silty clay	Loam sandy, Clay	Other classes
Organic Mater (%)	≥3	2–3	1–2	<1
N (%)	1≤	0.7–1	0.5–0.7	0.5>
K (mg kg^{-1})	200–250	150–200 and 250–300	100–150	<100
P (mg kg^{-1})	10–12	7–10 and12-15	5–7 and 15–18	<5 and >18
Ca (mg kg^{-1})	5–15	15–25	25–50	and >50<5
Fe (mg kg^{-1})	10–15	15–18 and 8–10	18–20 and 5–8	<5 and >20
Zn (mg kg^{-1})	0.9–1.1	1.1–2	2–6	>6 and <0.9

Table 4
Criteria for delineating land suitability of annual alfalfa in Aq-Qala region, Iran (Akinci et al., 2013; Bhagat et al., 2009; Ghafari et al., 2000; FAO, 1976; Kazemi et al., 2016; Sarkar, 2008; Sys et al., 1991).

Features	Highly Suitable (S1)	Suitable Moderately(S2)	Marginally Suitable (S3)	Non-Suitable (NS)
Precipitation (mm)	500<	450–500	300–450	<300
Average temperature (°C)	20–25	25–30	30–35	>35
Minimum temperature (°C)	10–15	5–10	0–5	<0
Maximum temperature (°C)	25–30	20–25	30–38	>38
Slope (%)	0–4	4–8	8–12	>12
Slope aspects	Plateau, south and southeast	East and northeast	Southwest and northwest	West and north
Elevation (m)	<1000	1000–1500	1500–2500	>2500
EC (dS.m^{-1})	0–3.5	3.5–5.5	5.5–10	>10
pH	6.5–7.5	5.5–6.5 and 7.5-8.5	5–5.5	<5
Soil texture	Loamy, Clay loam, clay, Sandy clay loam	Sandy loamy, Silty sandy loam, Sandy clay	Loam sandy, Silty loam	Sandy and Other classes
Organic Mater (%)	≥3	2–3	1–2	<1
N (%)	1≤	0.7–1	0.5–0.7	0.5>
K (mg kg^{-1})	200–300	150–200 and 300–350	100–150	<100 and >350
P (mg kg^{-1})	10–14	8–10 and 14–18	5–8 and 18–22	<5 and >22
Ca (mg kg^{-1})	10–20	5–10 and 20–30	30–50	>50 and <5
Fe (mg kg^{-1})	10–15	15–18 and 8–10	18–20 and 5–8	<5 and >20
Zn (mg kg^{-1})	1.5–2	1–1.5 and 2–4	4–6	>6 and <1

Table 5
The weights of criteria and sub-criteria in land suitability analysis of wheat, barley and alfalfa in Aq-Qala region, Iran (IR: Inconsistency Ratio).

Criteria /Sub criteria	wheat	barley	alfalfa	Criteria /Sub criteria	wheat	barley	alfalfa
1. Climate	0.569	0.442	0.559	3. Soil	0.323	0.420	0.328
Annual precipitation	0.680	0.684	0.537	EC	0.020	0.152	0.162
Average temperature	0.160	0.164	0.221	pH	0.073	0.071	0.076
Maximum temperature	0.080	0.082	0.150	Texture	0.063	0.069	0.052
Minimum temperature	0.080	0.070	0.092	Organic matter	0.304	0.238	0.176
				N	0.265	0.223	0.172
2. Topography	0.108	0.138	0.113	K	0.088	0.083	0.153
Slope	0.580	0.531	0.504	P	0.086	0.081	0.106
Aspect slope	0.350	0.295	0.345	Ca	0.039	0.035	0.037
Elevation	0.07	0.174	0.151	Fe	0.031	0.024	0.033
				Zn	0.031	0.024	0.033
IR	0.030	0.030	0.031				

to crop production with no limitations: S2 represents that the land unit is moderately suitable with severe limitations; S3 represents that the land unit is marginally suitable with server limitations; and NS represents that the land unit is unsuitable for crop growth (Zhang et al., 2015; Kazemi et al., 2015). In the final step, in order to assess the land suitability, the digital suitability layers of three crops were overlaid and integrated in GIS media by raster calculator functions. Then zoning of produced layer was done in 4 classes, including: highly suitable, moderately suitable and marginally suitable, were expected to have a crop yield of 80–100%, 60–80% and 40–60% of the yield under optimal conditions with practicable and economic inputs, respectively. Non-suitable land was assumed to have severe limitations which could rarely or never be overcome by economic use of inputs or management practices (Ghafari et al., 2000).

3. Result and discussion

3.1. Results of AHP analysis

The results indicated that the most important factors, according to their specific weighting were: climate, soil and topography. Also, among of the climate criteria, rain and minimum temperature had the highest and lowest weight, respectively. It should be noted that, among of the soil criteria, Ca, Fe and Zn, did not play a major role in the delineation of suitable areas for wheat, barley and alfalfa production (Table 5). Lai et al. (2002) applied AHP in group decision making, which has proved to be more beneficial than the conventional techniques such as the Delphi techniques. In general, this method, as compared to Delphi, allows participants to evaluate and discuss tasks more comprehensively. With several rounds of discussion and weight evaluation, participants are exposed to the decision task repeatedly for a more thorough and systematic analysis until a consensus is reached. In general, combining the potential of GIS with AHP analysis enables us to understand the potential value of the three crops production in this region.

3.2. Land suitability

Highly suitable regions were identified as sites that are highly advantageous for the performance of ley-farming. These areas covered an area of 35,495.20 ha, which represented 35.1% of total evaluating area (Table 6). Highly suitable areas were characterized by precipitation >400 mm during the crop growth cycle, elevation levels between 0 and 1000 m, slope <4%, soil pH level range of 6.5–7.5, EC < 4 dS m^{-1}, organic matter amounts range of 2–3%, and soil texture classes of loam, clay loam and silty clay loam. Therefore, the highly suitable (S1) areas have a high potential production and sustainability of yield from year to year (Ghafari et al., 2000). van-Eekeren et al. (2008) found that cereal fields incorporating leys had significantly greater amount of soil organic matter and total nitrogen than annually cropped cereal fields after 36 years. Various studies around the world have shown that perennial grass-legume pastures are effective for increasing soil quality compared to annual cropping systems (Dalal et al., 1995; Franzluebbers 2000; Gentile et al., 2005; Franzluebbers and Stuedemann, 2009; Bell et al., 2012). Also, according to the generated agricultural land use suitability map, it was determinate that, while 30.2% (33,725.60 ha) of the region is moderately suitable (S2) for ley-farming performance, 19.5% (23,245.74 ha) is marginally suitable (S3) and, 15.2% (20,681.77 ha) is non-suitable (NS) (Table 6). Highly suitable, moderately suitable and less suitable lands were expected to have a crop yield of 80–100%, 60–80% and 40–60% of the yield under optimal conditions with practicable and economic inputs, respectively (Kazemi et al., 2015). It is found that the most areas of the southern and central parts of Aq-Qala are the highly and moderately suitable regions. It is found that the moderately suitable class (S2) was located in central and southeast of Aq-Qala township (Fig. 3). This class characterized by: annual precipitation between 200 and 400 mm, slope in 4–8%, organic matter between 2 and 3%, EC 3.5–8 dS m^{-1} and annual average temperature of 12–20 °C.

Table 6
The distribution of land suitability degree for ley farming system performance in Aq-Qala township based on area and percentage.

Suitability degree	Total area classified by the suitability analysis	
	ha	%
High suitable (S1)	35495.20	35.1
Moderately suitable (S2)	33725.60	30.2
Marginally suitable (S3)	23245.74	19.5
Non-suitable (NS)	20681.77	15.2

Marginally suitable (S3) areas are those with variable potential production from year to year, with considerable associated risks of low yields, high economic costs, or difficulties in maintaining continuity of output, which are due to the climate interacting with soil properties or disease and pest problems (Ghafari et al., 2000). Along with the removal of restrictions such as soil fertility, suitability level could be enhanced in this class. Proper land management practices, leaching, drainage, land preparation, crop rotation, specific irrigation methods and using resistant crop help to increase crop yield in this area.

Our results, based on long-term climate data, showed that wheat, barley and alfalfa are not faced by limiting temperatures during the growing season. It is found that the most areas of the southern and central parts of Aq-Qala are the highly and moderately suitable regions (Fig. 3). It is because moderate rainfall, medium soil pH, low EC, high content of soil organic matter, K and P in these regions. Wheat and barley are reasonably widely adapted and performed well in many areas of Aq-Qala. Production practices, equipment needs, production costs and the growing season

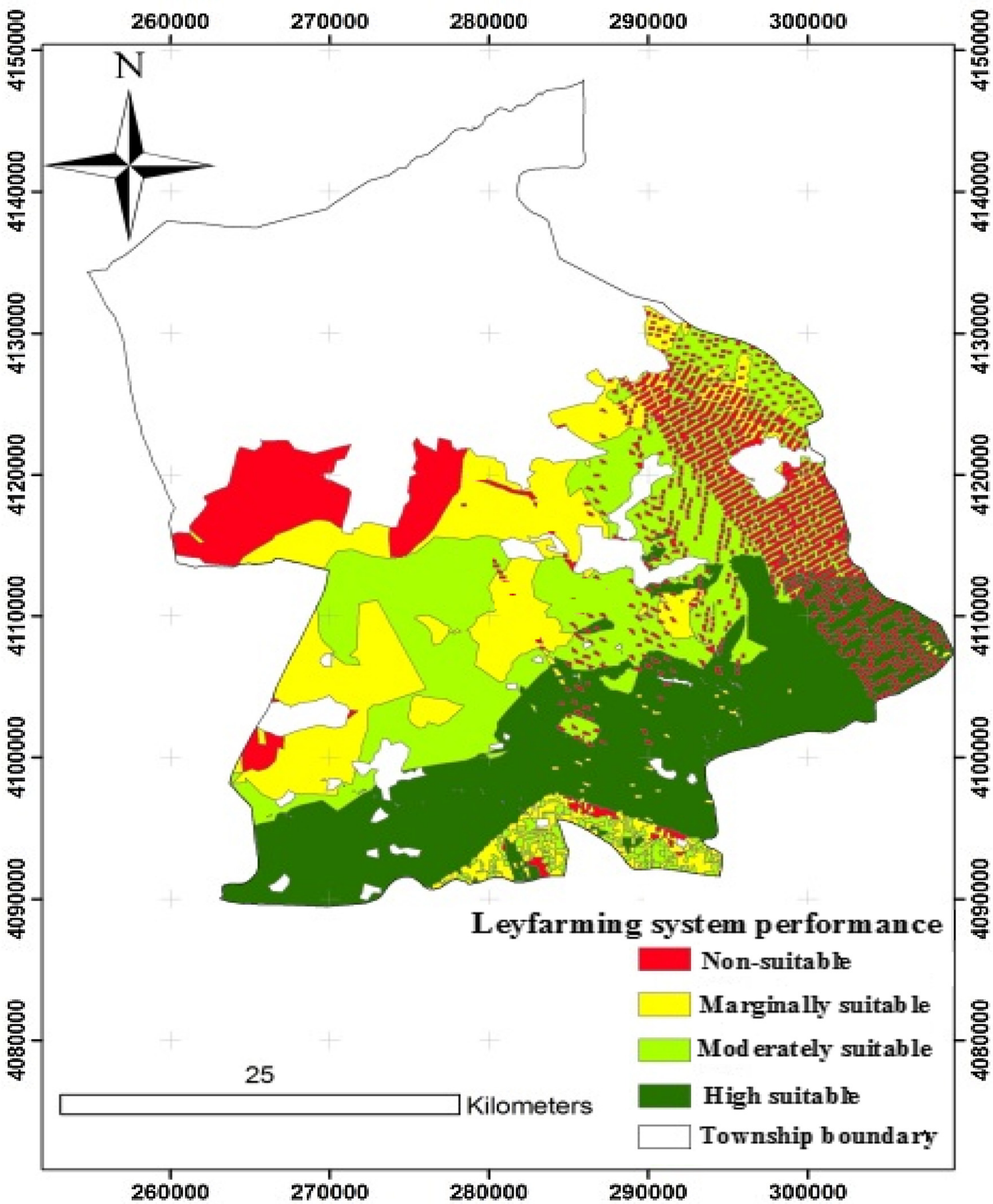

Fig. 3. Feasibility of leyfarming system performance in agricultural lands of Aq-Qala region, Iran.

for barley are the same as wheat. The land which is suitable for wheat based on overlaid layers is also suitable for the cultivation of barley. Also, annual alfalfa is actually grown in 323 ha area in this region, the results from the present study indicated that the potential area where alfalfa can be successfully cultivated in 35,495.20 ha. In this region, ley farming as a system of rotating crops with legume or grass pastures can be improved soil structure and fertility and disrupted pest and disease lifecycles. Also, it led to increased cereal yields and greater sheep and cattle production. Howieson et al. (2000) listed a range of benefits for incorporating forage legumes into farming systems. These include their ability to fix atmospheric nitrogen, ability to increase soil fertility and structure and capacity to break disease and pest life cycles of crops when grown in rotation. Navas et al. (2011) indicated that the legume crop covers influenced the soil quality positively. They are recommended *Centrosema macrocarpum* as a cover crop to establish a ley farming system in the savannas of eastern Venzuela.

In ley farming systems, the poor regeneration and therefore the poor persistence of annual medics is one of the major problems deterring farmers from employing alfalfa. Insufficient seed reserves and unfavorable distribution of seeds within the soil profile after being rotated with a wheat crop are regarded as important factors responsible for poor regeneration and persistence of alfalfas (Carter, 1987). Ramos et al. (2010) suggested that seeding a fallow pasture with a mixture of fodder species, and using sheep for introducing these fodder species in a fallow while manuring

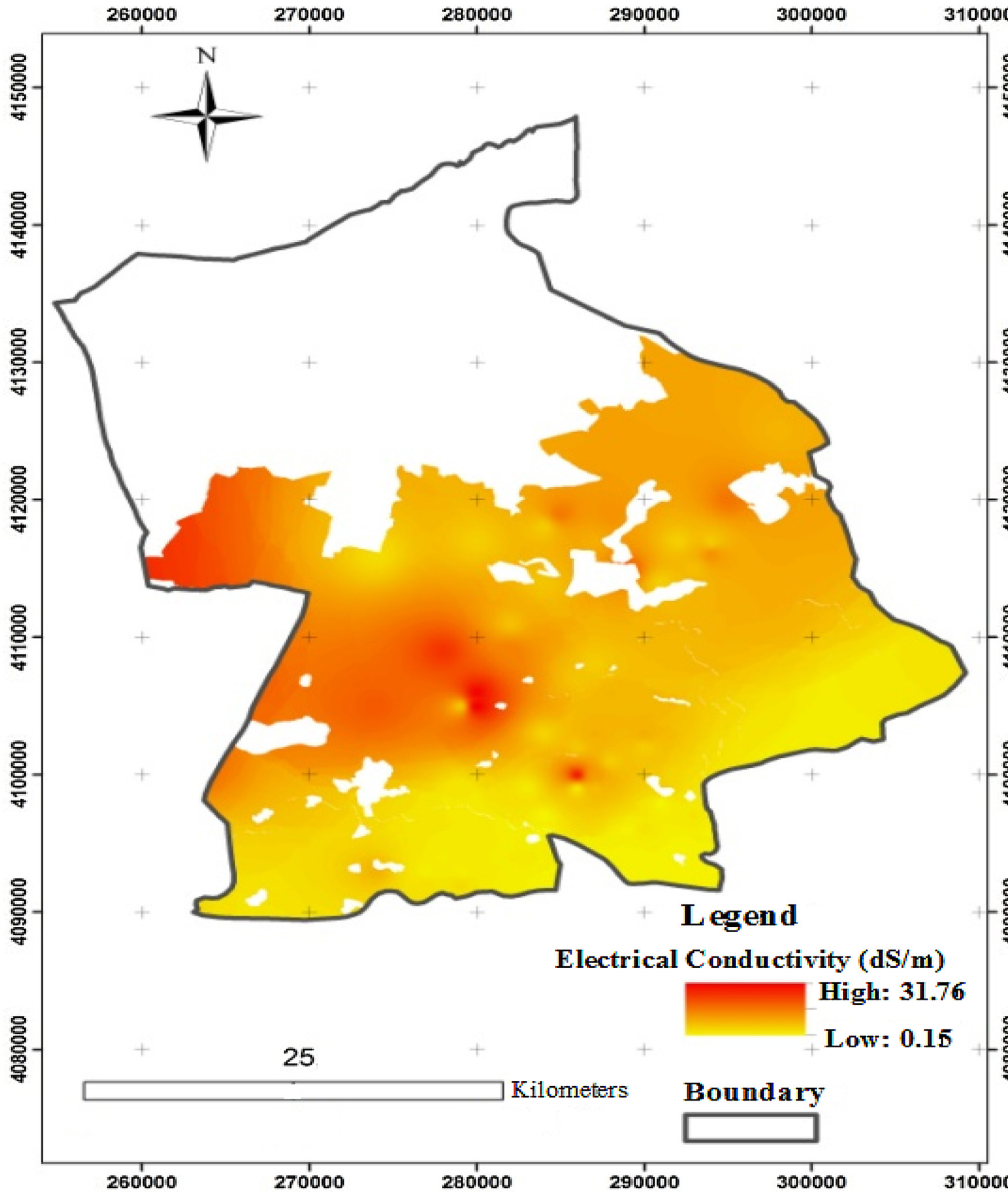

Fig. 4. Electrical Conductivity (EC) distribution in agricultural lands of Aq-Qala region, Iran.

may improve fallow pasture quality in semiarid Mediterranean environments. Nevertheless, hard-seeded species should be used when introducing new high fodder quality species into pastures by means of livestock decomposition. In general, species selection to ensure successful establishment and minimize maintenance cost, should follow three basic criteria; high feeding value, adaptation to pedoclimatic conditions, and self-reseeding ability (Talamucci and Pardini, 1999).

The results showed that the topographic characteristics of this region were suitable for the growth of wheat, barley and annual alfalfa. There are some main variables, such as salinity and low rainfall, which limit both suitable land area and actual yield. Among the environmental variables that limit agricultural production in this region, EC is the most prominent (Fig. 4). There are marginally suitable areas in the eastern and northern parts of the investigated regions (Fig. 3) because of insufficient rainfall and high EC, accounting for 19.5% of the whole region (Table 6). Land classified as NS has a very low capacity of sustaining the ley farming system, since high EC, low OM and low rainfall are the key limiting factors in these areas. These regions were disadvantageous for cultivation of crops. These areas were mainly distributed in the northern and western regions of Aq-Qala (Fig. 3). Most of the areas are so saline that they are not conducive to the cultivation of crops. Salinity is a serious problem in the north of Aq-Qala township. EC in this region is higher than 10 $dS\,m^{-1}$ (Fig. 4). Thus, wheat, barley and alfalfa could not be blindly cultivated in these areas. It is clear that analysis of soil salinity is essential for understanding the environmental degradation processes in the region. However, to be able to utilize these regions, soil amendment and irrigating are suggested. Ashraf et al. (2010) stated that the salinity, exchangeable sodium and gravel were most important limiting factors for the growth of irrigated wheat in Damghan plains (center of Iran), also this area was unsuitable for rainfed wheat. Generally, in Iran, the most of agricultural products are being produced in an unsustainable way, but it is still possible to improve land productivity and achieve optimal exploitation of natural resources. Sustainable agriculture could be achieved if the enormous potential in this sector is developed (Sohrabi, 2003). Also, specific environmental constraints to forage production need to be addressed through pasture legume breeding and selection. In Australia, the results of Rogers et al. (2006) suggested a range of tolerance within Medicago *polymorpha* and several *Melilotus* species that could be exploited for breeding.

4. Conclusion

This research was conducted in the northern part of Iran, in Aq-Qala township, a semi-arid region, during the 2014. It provides a methodological approach to assessing the suitability of agricultural lands for ley farming performance. This methodology combines environmental data with expert-based judgments about the effects. The evaluation of land use suitability for ley-farming refers to comprehensive evaluation of climatic, soil and topographic suitability for cultivation of wheat, barley and self seeding alfalfa. Our results also confirmed that Geographic Information Systems plays an important role in this study as a platform for preparation, management and representation of spatial data. The results revealed that 35.1%, 30.2%, and 19.05% of the land area were high, moderate and marginally suitable for ley farming system performance in Aq-Qala, respectively. The non-suitable areas were mainly distributed in the northern and western regions of studied township. Most of the areas are so saline, as they are not conducive to the cultivation of these crops. The results showed that the high EC, low OM and low rainfall are the key limiting factors in these areas. We recommend that for more clarification, the same studies using other soil parameters such as magnesium and boron contents also should be planned. In general, this research is a biophysical evaluation that provides regional scale information which could be used to performance of ley-farming system. It is useful for decision markers to determine the quality of croplands for this rotation system as a decision and planning support tool. This study could also serve as a reference especially in developing agricultural countries. Also, this investigation provides information at local level that could be used by farmers to select cropping patterns and crop rotations in accordance with land use suitability results.

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