soil systems

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Review

A Contribution to Soil Fertility Assessment for Arid and Semi-Arid Lands

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Abstract: Soil fertility must be viewed as a dynamic concept that involves the constant cycling of nutrients between organic and inorganic forms. In this context, it refers also to supply adequate amounts of water and aeration for plant growth. Soil fertility under arid and semi-arid lands is constrained not only by limited water availability but also by small organic matter contents. Most fertility assessment systems are based on organic matter contents as the main parameter. However, crop experiments from various irrigated arid and semi-arid soils indicate that productivity is less-affected by organic matter contents than assumed. Therefore, we propose a new soil fertility system for dryland soils. It is a rule-based set of algorithms, mainly using additions and subtractions. Soil, climate, and landscape factors are integrated to calculate the numerical value of fertility for a given soil. We expect the system, which is focused on soil properties that keep or increase optimum soil moisture (such as texture), to be applicable in arid and semi-arid lands and to provide more realistic estimates of fertility regarding agricultural purposes. The manuscript will provide an outline of the main aspects of the system, illustrated by various case applications.

Keywords: nonagricultural land; nutrients; organic matter; water retention; inherent fertility; acquired fertility

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1. Introduction

The increasing population and the demand for high-quality food are the most pressing issues of current global food security. This shows the necessity of developing and using the land, especially areas that have been overlooked so far. In this context, the vast soil resources of arid and semi-arid lands are a potential agricultural habitat accounting for more than 50% of the total land surface [1]. However, these lands are not always considered as long as more favorable conditions can be found elsewhere. The international policy community regards the soil in the arid and semi-arid areas as increasingly important for world development issues. Such as food security, poverty alleviation, land degradation, and the provision of environmental services [2–4]. However, the problems connected with the agricultural use of the arid and semi-arid lands are of a very intricate nature. Most of the developing countries with high population growth are in the arid and semi-arid climate belt. Undoubtedly, the rapid development of their natural food resources is crucial to their existence and stability. It is known that available soil water is a prerequisite for plant growth. Therefore, soil moisture is the main limiting factor in most agricultural systems [5–9]. In all climates suitable for agriculture, the water storage capacity of soils is a crucial property for soil functionality including the productivity function [10–12] and is closely correlated with crop yields [13,14]. Consequently, the ability of the soil to provide adequate moisture to the farmed plants is the decisive factor in obtaining yields under the conditions of arid and semi-arid regions. However, all the factors that assist or increase soil moisture retention are not evaluated when assessing soil fertility. The reason for this is that most soil fertility estimation systems are designed for temperate-humid areas that do not suffer from problems with lack of moisture in the soil.

2. The Concept of Soil Fertility

Soil fertility must be viewed on the basis that it is a dynamic concept that changes with the changing conditions prevailing in a region. This concept calls for continuous review as long as there are high yield plant varieties released that demand higher nutritional requerments. In general, soil fertility is a complex quality that is related to the inherent ability of soils to provide plants with nutrients [15–17] a result of biological, chemical, and physical processes that involve the constant cycling of nutrients between organic and inorganic forms. According to [18,19], soil fertility is not only the ability of the soil to supply the essential nutrients for plant growth but also the ability to supply adequate amounts of soil water. Since soil productivity is the capacity of soil to produce crops per unit area, soil fertility is a component of soil productivity that is strongly affected by management. In contrast, the other components of soil productivity such as soil depth, landscape (slope), or climate, are largely related to the soil itself. Often these are static year after year and determine the limiting factors of productivity [20–23].

Depending on the origin and sources of fertility, it can be divided into two types:

(1) Inherent or natural fertility: it indicates the soil natural content of plant nutrients.
(2) Acquired fertility: it indicates the soil nutrient content resulting from the application of fertilizing, plowing, irrigation.

Generally, soil fertility increases as the soil organic matter content increases. No doubt that organic matter improves the physical condition, as well as its decomposition increases the nitrogen content in the soil.

The natural fertility of the soil can be maximal or restricted according to the following soil characteristics:

- The existence of toxic substances, which may inhibit plant growth.
- Sufficient soil depth for adequate root growth and water retention.
- Good internal drainage, allowing sufficient aeration for optimal root growth.
- Soil pH in the range 5.5 to 7.0 (suitable for most plants but some prefer or tolerate more acid or alkaline conditions).
- Presence of a range of microorganisms that support plant growth.
- Stable surface soil.

3. Characteristics of Arid and Semi-Arid Areas and Characterization of Climate and Conditions

The general characteristics of arid and semi-arid regions are low rainfall and high temperatures, and hence high evaporation, with a soil moisture regime of aridic and xeric and a soil temperature regime of mesic, thermic, and hypothermic [24]. As a result, the soils in these areas show a low natural primary productivity and restricted fertility due to the lack of water. Arid soils often have a high alkaline pH and accumulate potassium, sodium, calcium, and other minerals in high concentrations, ultimately damaging plant life. This is because carbon will bond with oxygen to form carbonates in the absence of water and later cations, which will actively repel water. This can lead to carbonates or gypsic crust forms that prevent water from reaching plant roots.

Soil fertility under arid and semi-arid conditions is constrained by environmental extremes of hot and cold temperatures, as well as by low water availability. With some exceptions, these soils have inherently low fertility, low availability of nitrogen and phosphorus, low water-holding capacity, high pH, low soil organic matter (ranging from 0.1 to 3%), shallowness, stoniness, and other specific problems [25–31]. This is caused by the lack of inputs of organic matter and nutrients from external sources with these areas being subject to low rainfall and high temperatures. These areas are fairly widespread, covering around 30–40% of the world's terrestrial surface. Given the vulnerability of these lands to degradation, it is estimated that some 44 million km^2, corresponding to 34% of the total world's area and supports 2.6 billion people, is at risk of desertification [32]. Therefore, these lands should be considered as being of great global importance even if the potential for agricultural production is relatively low. However, this does not mean that it is not productive or not fertile but rather that there are differences in fertility parameters.

It is evident that the soil fertility status that supports rainfed production systems in these areas has not been given any attention. Nevertheless, it is proven that these soils only support sparse vegetation and have low natural primary production. It follows that its inherent natural fertility is relatively low. In this kind of soil, water shortage is a major obstacle to be reckoned with, which controls not only productivity but also the maintenance of soil fertility. When the soil's moisture retention capacity is increases, also soil fertility in arid an semi-arid lands can be improved. Hence, to sustain soil productivity, both water shortage and soil sterility problems must be addressed simultaneously. The main soil environmental concerns in arid and semi-arid areas are not primarily related to nutrient pollution as in the temperate zone but rather to the opposite nutrient depletion as well as the loss of soil organic matter (SOM) and its related functions [33,34]. Nutrient depletion or loss has been reported under the traditional farming system [35]. Nutrient loss is caused by bush burning, mixed cropping without proper use of fertilizers, and so on. Even though external inputs can increase productivity and contribute to sustainability, the excessive use of inputs such as fertilizers, even so-called "economic" levels, is usually prohibitively costly in dry areas [36]. It is unlikely that drylands can ever be competitive for grain production with the subsidized producers in North America, Europe, and elsewhere since dry areas generally have low overall potential given their water and soil constraints.

4. Problems of Estimating Soil Fertility in Arid and Semi-Arid Regions

There is a need for a critical review of the approaches for estimating soil fertility, especially regarding arid and semi-arid areas. As know, a plethora of soil fertility estimation methods are used under different conditions. Most of which have been tailored according to the requirements and characteristics of humid temperate regions as most of the global agricultural production comes from these areas. However, arid and semi-arid regions cover the greates part of our planet and considered as potential areas for agriculture expansion after overcoming obstacles that limit or prevent its investment. It is evident that little attention has been paid to determining the fertility status as well as building up the fertility of the soil in arid and semi-arid areas in the past supporting rainfed production systems since these soils are relatively more fragile and widespread degraded comparing to other soils. However, as in the case of other agroecosystems, the soils of the arid and semi-arid areas vary widely in various fertility parameters. While most of the methods from humid temperate regions assess the adequacy of fertility parameters (C_{org}, N. P. K), most do not put a notable focus on limiting soil factors. The latter is consistent with arid and semi-arid lands since the true limits on soil use are the negative characteristics according to Liebig's law of the minimum, regardless of the degree of suitability of the most favorable properties. A simple comparison was made between the fertility characteristics of two different types of soils under (semi-arid and arid) climatic conditions. The first soil is Haploxeroll from the El-Ghab area in central Syria receives 600 mm annually in the rainy season (September-May). The second soil is Gypsiorthid from the Beer Al-Hashem area in eastern Syria receives 200 mm annually in the rainy season (September-May). Both areas are subject to irrigated agriculture. The result of the chemical analysis was compared to some of the main fertility parameters of both soils (Table 1). It is very evident that the fertility of the first soil is higher than of the second one.

Table 1. Soil fertility parameters of two soils from semi-arid and arid areas of Syria.

Haploxerolls (600 mm Rainfall, Irrigated), Coordinates: 35°23′58.21″ N 36°19′46.12″ E				
Depth (cm)	Ex. K (mg.kg^{-1})	Av. P (mg.kg^{-1})	Tot. N (%)	OM%
0–30	275	11.8	0.15	4.2
30–60	277	8.2	0.09	3.1
60+	85	3.3	0.02	2.2
Gypsiorthids (200 mm Rainfall, Irrigated), Coordinates: 36° 4′0.91″ N 38°56′8.32″ E				
Depth (cm)	Ex. K (mg.kg^{-1})	Av. P (mg.kg^{-1})	Tot. N (%)	OM%
0–30	162	8.9	0.06	0.5
30–60	155	7.7	0.07	0.34
60+	134	2.2	0.01	0.0

Another comparison was made for both previous soils over a period of ten years to find out the mean crop yield from each soil. The high variation in fertility indicators for both soils did not reflect sharply on crop yield (soil productivity), as there was a slight difference in productivity, but it never reflects the high variation in fertility indicators (Table 2).

Table 2. The average of ten years crop yield from El-Ghab (Haploxerolls) and Beer Al-Hashem (Gypsiorthids).

Year	El Ghab Haploxerolls			Beer Al Hashem Gypsiorthids		
	Irrigated Durum Wheat	Irrigated Soft Wheat	Cotton	Irrigated Durum Wheat	Irrigated Soft Wheat	Cotton
2001	5052	5743	5010	4890	5192	4743
2002	4891	5046	4970	4710	4943	4227
2003	3875	4236	4230	4023	4174	3983
2004	6131	6727	5702	5207	5534	4839
2005	4632	5107	4830	4362	4826	4296
2006	5274	5482	4628	4927	5105	4285
2007	3746	4209	3867	4281	4371	3942
2008	5862	6011	5392	5120	5429	5173
2009	4963	5296	4973	4460	4739	4395
2010	5923	6207	5427	5739	5839	4947
Mean	5034 kg/ha	5406 kg/ha	4902 kg/ha	4771 kg/ha	5012 kg/ha	4482 kg/ha

This previous comparison shows that the productivity of both soils is almost similar, although the traditional fertility indicators (C_{org}, N. P. K) are completely different. This can be concluded as the soil fertility assessment systems developed by researchers and scientists for temperate and humid areas have a low potential for adoption in arid and semi-arid areas, in light of the fact that the existence of subtle environmental conditions, which these systems did not take into account. Scientific recommendations that are sound and relevant for a particular area can be of no value at other sites. Thus, to ensure adoption and practical applicability, soil fertility assessment systems specific to arid and semi-arid regions should be developed.

In most of the literature on estimating soil fertility in humid temperate regions, the presence of organic matter and major plant nutrients (N, P, K) are used as an indicator of soil fertility (chemical fertility) is largely true. There is little research on the role of physical properties of soil in productivity (physical fertility), especially concerning those characteristics that help retain more moisture. The ability of soils to retain moisture must be given more attention [21], as water is the medium in which most of the processes of converting nutrients into a form suitable for plant take place.

Extreme conditions such as low and erratic precipitation, high temperatures, and strong dry winds are the predominant climatic features of drylands represented by the large region of Central and West Asia and North Africa (CWANA). This makes water scarcity the most restrictive factor for crop production rather than the availability of nutrients and soil fertility. Thus, conservation and effective utilization of water is a prerequisite for greater availability and more efficient uptake of nutrients. Nutrient cycling in drylands is affected by low and erratic rainfall, wide temperature extremes, alkalinity and/or salinity, and occasionally by relatively high rates of dry deposition of nutrient-enriched soil particles from wind erosion. The utilization of soil nutrients by plants is also closely related to the moisture state of the soil. For example, nitrogen is more efficiently used under ideal soil moisture conditions.

5. Results

The Proposed System

The soil fertility evaluation system for arid and semi-arid lands (SFAL) is a percentile system in which it consists of three rating categories that interpret different soil properties to identify soil fertility constraints. A set of indicators in terms of good, medium, or poor will be used. The score will be converted into a numerical value using scoring tables ranking from best conditions to worst. The final score of a given soil will be within a 100-point scale.

The rating levels are:

I. Limiting Soil Factors,
II. Soil physical and chemical properties,
III. Modifiers.

The first category of limiting soil factors contains three parameters that are critical for agriculture and are limiting the total soil quality. These constraints are the result of extremes of soil-forming factors. The limiting soil factors are defined as those properties and characteristics of the soil and landscape that influence the growth of crops. These factors are hard to control or mitigate. Additionally, they decisively control the possibility of plant presence in a given soil by the size of the available roots (soil depth), the stability of the soil surface (slope), and the conditions of internal soil aeration (ponding conditions) [37] (Table 3).

Table 3. The Limiting Soil Factors of (SFAL).

I-Limiting Soil Factors		
Class%	**Description**	**Value**
Effective Rooting Depth (cm)		
1–5	Very shallow	0
6–10	Shallow	1
11–30	Moderately shallow	2
31–60	Somewhat deep	8
61–100	Moderately deep	10
101–200	Deep	12
>200	Very deep	14
Soil depth is critical on shallow soils over non-renewable substrata such as hard rock [38] or hard ban.		
Slope Gradient (%)		
>60	Very steep	0
60–30	Steep	1
29–15	Moderately steep	2

Table 3. *Cont.*

I-Limiting Soil Factors		
Class%	**Description**	**Value**
14–10	Strongly sloping	3
9–5	Sloping	4
4–2	Gently sloping	5
1.9–1	Very gentle sloping	6
0.9–0.5	Nearly level	7
0.4–0.2	Level	8
0.1–0	Flat	9
Ponding Conditions (cm/≥continuous 30 days)		
≤5	Surface	0
5–10	Extremely shallow	1
11–20	Very shallow	2
21–30	Shallow	3
31–40	Somewhat deep	4
41–50	Moderately deep	5
51–100	Deep	6
>100	Very deep	7

The second category deals with the physical and chemical properties of the soil profile. Each parameter is defined in Table 4.

Table 4. Soil Physical and Chemical Properties of (SFAL).

II-Soil Physical and Chemical Properties		
Class%	**Description**	**Value**
Salinity (ECe/dS.m^{-1})		
≥32	Ultra-saline	1
31–16	Extremely saline	2
15.9–8	Very strongly saline	3
7.9–4	Strongly saline	4
3.9–2	Moderately saline	5
1.9–1	Slightly saline	6
0.9–0.5	Very slightly saline	7
<0.5	Non saline	8
Carbonates (%)		
≥80	Extremely carbonates	1
79–60	Very strongly carbonates	2
59–40	Strongly carbonates	3
39–30	Somewhat strongly carbonates	4
29–20	Moderately carbonates	5
19–15	Slightly carbonates	6
<15	Very slightly carbonates	8
Surface Coarse Fragments (%)		
>80	Dominant	1
79–40	Abundant	2
39–15	Many	3
14–5	Common	4
4–2	Few	5
1–0.5	Very few	6
0	None	7

Table 4. *Cont.*

II-Soil Physical and Chemical Properties		
Class%	**Description**	**Value**
Solum Textural Class		
Sand		1
Loamy sand		2
Sandy loam		3
Loam		4
Clay loam		5
Silty loam		6
Clay loam/Clay		7
Exchangeable Sodium Percentage (ESP%)		
≥50	Extremely alkaline	1
49–30	Strongly alkaline	2
29–15	Alkaline	3
14–5	Slightly alkaline	4
<5	Non alkaline	5
pH		
≥9.5	Extremely alkaline	1
≥4	Extremely acid	1
9.5–9	Very Strongly alkaline	2
4–5	Very strongly acid	2
9–8.5	Strongly alkaline	3
5–5.5	Strongly acid	3
8.5–8	Moderately alkaline	4
5.5–6	Moderately acid	4
8–7.5	Slightly alkaline	5
6–6.5	Slightly acidic	5
Drainage		
Subaqueous drainage	-	1
Excessively drained	-	1
Very poorly drained	-	2
Somewhat excessively drained	-	2
Poorly drained	-	3
Somewhat poorly drained	-	4
Moderately well-drained	-	5
Well-drained	-	6

The third category includes the modifiers, which includes fertile parameters (Table 5).

Table 5. The modifiers of (SFAL).

III-Modifiers		
Class%	**Description**	**Value**
Organic Carbon Content (C_{org}%)		
<0.3	Very poor	0.5
0.31–0.6	Poor	1
0.61–0.9	Somewhat moderate	1.5
0.91–1.5	Moderate	2
1.51–3	Rich	2.5
31–6	Very rich	3
>6	Extremely rich	4

Table 5. *Cont.*

III-Modifiers		
Class%	**Description**	**Value**
Total Nitrogen (Tot. N %)		
≤0.01	Very poor	0.5
0.011–0.05	Poor	1
0.06–0.1	Somewhat moderate	1.5
0.11–0.15	Moderate	2
0.16–0.2	Rich	2.5
>0.2	Very rich	3
Available Phosphorus (mg.kg^{-1})		
<7	Very poor	0.5
8–9	Poor	1
10–20	Somewhat moderate	1.5
21–35	Moderate	2
36–50	Rich	2.5
>50	Very rich	3
Exchangeable Potassium (mg.kg^{-1})		
<80	Very poor	0.5
81–160	Poor	1.5
161–240	Somewhat moderate	2
241–320	Moderate	2.5
>320	Rich	3

The calculation of numerical values attached to each parameter results in a value that determines the fertility row to which the soil belongs (Table 6):

Table 6. The calculation of numerical values of (SFAL) parameters.

Value	Description	Class
• Σ value <10 or one of the factors limiting production is (0)	Nonagricultural land	X
• Σ value <20 or one of the factors limiting production is (1)	Soil with serious problems	IX
• Σ value <30 or one of the limiting factors is (2)	Soil with problems	VIII
• Σ value >30–≤40	Very poor	VII
• Σ value >40–≤50	Poor	VI
• Σ value >50–≤60	Somewhat moderate	V
• Σ value >60–≤70	Moderate	IV
• Σ value >70–≤80	Good	III
• Σ value >80–≤90	Very good	II
• Σ value >90	Excellent	I

The (SFAL) presented the Figures 1–4 with comparisons to three systems: Soil Fertility Capability Classification (FCC) [39], Muencheberg (SQR) [40] and Storie Index (SI) systems [41].

Profile 1: Ansar farm, Slope: 1.5%, Ponding 40cm, Drainage: Somewhat poorly drained

	Depth (cm)	$CaSO_4$ $2H_2O$	$CaCO_3$ (%)	texture	ECe ($mS.m^{-1}$)
1	40	2.77	47	cl	28

ESP (%)	pH	C_{org} (%)	Tot. N (%)	Av. P ($mg.kg^{-1}$)	Ex. K ($mg.kg^{-1}$)
33	7.74	0.38	0.021	7.6	230

I	-
II	-
III	-
Value	2
Class VIII	Soil with problems

FCC	LdsnO
Muencheberg (SQR)	15 Very poor
Storie Index (SI)	4% Nonagricultural

Figure 1. Soil of Ansar farm, Syria, Coordinates 36°1′59.52″ N, 38°47′57.21″ E.

Profile 2: El Rafeqa, Slope: 1.8%, Ponding >100cm, Drainage: Excessively

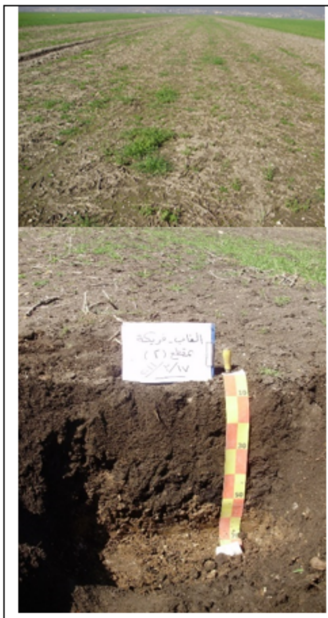
	Depth (cm)	$CaSO_4$ $2H_2O$ (%)	$CaCO_3$ (%)	texture	ECe ($mS.m^{-1}$)
1	15	2.77	24.36	1	0.17
2	-	8.14	23.52	cl	7.93

ESP (%)	pH	C_{org} (%)	Tot. N (%)	Av. P ($mg.kg^{-1}$)	Ex. K ($mg.kg^{-1}$)
-	7.74	0.40	0.041	10.50	938.9
-	7.51	0.23	0.023	3.20	299.6

I	15
II	30
III	6
Value	51
Class V	Somewhat moderate

FCC	C'L"dbs
Muencheberg (SQR)	Poor
Storie Index (SI)	14% Very poor

Figure 2. Soil of El Rafeqa, Syria, Coordinates 36°2′23.92″ N, 38°50′31.61″ E.



Profile 3: El Ghab, Slope: 1.5%, Ponding 50cm, Drainage: Somewhat poorly drained

	Depth (cm)	$CaSO_4\,2H_2O$ (%)	$CaCO_3$	texture	ECe ($mS.m^{-1}$)
1	26	0	17.36	c	1.6
2	34	0	27.52	cl	2.1

ESP (%)	pH	C_{org}	Tot. N (%)	Av. P ($mg.kg^{-1}$)	Ex. K ($mg.kg^{-1}$)
2	7.7	1.40	0.09	11.0	620.9
4	8.0	0.9	0.04	6.0	430.6

I	10 + 6 + 5 = 21
II	6 + 6 + 6 + 7 + 5 + 5 + 4 = 39
III	2 + 1.5 + 1.5 + 3 = 8
Value	68
Class IV	Moderate

FCC	Cdb
Muencheberg (SQR)	Moderate
Storie Index (SI)	55% Fair

Figure 3. Soil of El Ghab, Syria, Coordinates 34°9′.84″ N, 36°16′35.79″ E.

Profile 4: El Rouj plain, Slope: 0.5%, Ponding 80cm, Drainage: Moderately well-drained

	Depth (cm)	$CaSO_4\,2H_2O$ (%)	$CaCO_3$ (%)	texture	ECe ($mS.m^{-1}$)
1	170	0	17.1	c	0.51

ESP (%)	pH	C_{org} (%)	Tot. N (%)	Av. P ($mg.kg^{-1}$)	Ex. K ($mg.kg^{-1}$)
0	7.57	0.7	0.08	27.0	439.9

I	12 + 7 + 6 = 25
II	7 + 6 + 6 + 7 + 5 + 5 + 5 = 41
III	1.5 + 1.5 + 2 + 3 = 8
Value	72
Class III	Good

FCC	Cdiv
Muencheberg (SQR)	Good
Storie Index (SI)	70% Good

Figure 4. Soil of El Rouj plain, Syria, Coordinates 35°57′27.5″ N, 36°28′24.0″ E.

6. Discussion

The soil fertility estimation system is a rule-based set of algorithms that integrate soil, climate, and landscape factors to calculate the percentage value of fertility for a given soil. There are many interesting attempts to differentiate soil fertility with the help of numerical values; a distinction can be made between three mathematical methods:

-Additive systems (value number W = parameter A + parameter B + parameter C etc.)

-Multiplicative systems (W = A × B × C)

-Complex functions (W = A × √(B × C × D)), where A, B, C and D express soil and location factors.

The additive systems are used in Germany, Romania, Canada and India. Further, the FAO set up an index for evaluating the productivity of a soil based on the Storie index. It is calculated as follows:

Index = P x T x (N or S) x O x A x M x D x H, where P is the effective soil depth, T is the texture and structure of the A horizon, N is the base content, S is the content of dissolved salts, O is the proportion of organic material, A is the clay content, the clay type and mineral exchange capacity, M is the reserve on weatherable material in the B horizon, D describes the water discharge and H the soil moisture.

There are also complex functions which combine the mathematical methods with one another such as in Strzemski system [42].

Limitations of soil, water, or climate reduce the soil's productivity. These limitations increase the need for improved management practices. Appropriate management of moderately productive soils can result in higher yields, especially recent advances in fertility management in such high-risk and highly variable environments. Thus, we do not attempt to cover all of them but rather consider key issues from the fairly modal arid and semi-arid areas of Central and West Asia and North Africa. These are physical-climatic regions with temperate or steppe areas having typical Mediterranean climates of warm and cold seasons with winter rainfall. These differ from more tropical semi-arid areas or highland regions, which can have quite different rainfall and temperature patterns and different dryland farming systems [43].

A comparison between (SFAL), (FCC), (SQR) and Storie Index (SI) systems shows that the (FCC) did not consider the limiting soil factors that could lead to the exclusion of soils from cultivation. Although the Storie system consideration of slope values, it gives a similar rating for different slopes; for example (3–4%) slope rating (80–95%) and (45% and more) rating (5–80%). In addition, it did not give any importance to salinity and gypsum in the soil, which is considered one of the most important determinants of productivity in arid areas, and it completely ignored the problems of ponding and rising water table problems. Although the result of comparisons with Muencheberg (SQR) was very consistent, it does not put a great focus on problems related to the properties of soils in dry and semi-arid areas such as the accumulation of gypsum, which may lead to the exclusion of soils from agriculture, but rather deals with them in terms of climate only.

7. Conclusions

Although dry and semi-arid soils are widely spread, studies on fertility estimation on this type of soil are rare. These soils are characterized by a low content of organic matter, high phosphorus fixation, high pH, salinity, and alkalinity as well as the presence of carbonates and gypsum. Further on, the weathering is mainly physical with slight chemical reactions. Combined with the disruption of the nutrient cycle due to low soil moisture, all these factors have a negative impact on these soils and their productivity is largely restricted by conditions of the prevailing environment. Consequently, these characteristics make traditional systems used for estimating soil fertility in wet areas inappropriate for this type of soil.

In this proposed system, mathematical formulae are applied so that the final result can be expressed in numerical parametric terms, which, in turn, are converted into categories. This system is not hierarchical as it does not group the classes into a series of levels of importance. It contrasts, it is rather categorical, in which each category can easily be distinguished from the others and be applied accordingly.

The systems that are merely based on soil parameters enable an evaluation that is usually correct from the theoretic standpoint, but the evaluations do not reflect real conditions to a great extent since they do not take serious consequences of mutual implicit soil and landscape factors into account. In this system, however, the soil and landscape parameters are integrated into parametric methods, making the system simple, objective, quantitative, reliable, easy to understand and apply even by the non-specialists, and are easy to modify and adapt to new uses as demands for food and fiber production on these kinds of soils are increasing.

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