Relationship of soil physicochemical properties with elevation and geographical directions

Imran1, Amanullah1, S Naveed2, I Khan1, M Sajid3, T Mahmood3, I Hussain1, M Ilyas1, I Ali3, S Ullah4, A Kamal5, A R Al-Tawaha6, D Thangadurai7, J Sangeetha8, A Rauf9, P Saranraj10, W Al-Sultan11, D K A AL-Taey12, Refat 11, A Youssef 13, S N Sirajuddin14, and Hastang14

1Faculty of crop production sciences, The University of Agriculture Peshawar Pakistan
2Department of Botany, GGDC Karak
3Department of Agriculture, Hazara University Mansehra, Pakistan
4Key Laboratory of Crop cultivation and farming system, College of Agriculture, Guangxi University, China
5Department of Biological Sciences, Al-Hussein bin Talal University, Maan, Jordan
6Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
7Department of Botany, Karnatak University, Dharwad, 580003, Karnataka, India
8Department of Environmental Science, Central University of Kerala, Kasaragod, 671316, Kerala, India
9Department of Chemistry, University of Swabi, Anbar, Khyber Pakhtunkhwa, Pakistan ICAR-Central
10Department of Microbiology, Sacred Heart College (Autonomous), Tirupattur, Tamil Nadu, India
11Department of plant protection, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
12Department of Horticulture, Faculty of Agriculture, Al-Qasim Green University, Babylon Province, Baghdad, Iraq
13Soils and Water Use Department, National Research Centre, Dokki, Giza, Egypt
14Department of socio economics, Faculty of Animal Science, Hasanuddin University, Makassar Indonesia

Email: imranagrarian@aup.edu.pk

Abstract: The core findings of this study revealed that physicochemical properties fluctuate with soil texture and soil class. Sandy soil showed inconsistent variation with geographical directions. Bulk density, lime content, EC and pH decreases with topography and soil elevation while these parameters increased from surface to subsurface soil within a profile. Nitrogen, phosphorus, potassium and micronutrient increased with increase in elevation. All these parameters decreased from surface to subsurface soil. Water holding capacity and saturation percentage increased with increase in elevation, while decreased from surface to subsurface soil. Based on the critical level of phosphorus, the altitude was low in available P and available P was quite low than the crop requirements and so they will be classified as phosphorus-deficient soils.
1. Introduction
Soil Physico-chemical and biological properties detrimentally affect the suitability of the soil for crop production. Similarly, Soil erosion is one of the natural Causes that affect soil properties which ultimately affect crop production [1–4] reported that with an increase in the severity of erosion potentially increased B.D and decreasing total porosity and saturation (%). In another study by [5] it was found that organic matter, available P and K decreased significantly in the Ap and B-horizons due to erosion.

Trace elements and heavy metals occur naturally in the earth crust and they enter the soil by natural processes like mineral weathering of parent material and by different anthropogenic processes, one of them including a direct application of phosphate fertilizers to soil [6]. Soil properties are key factors influencing the distribution of available Fe, Mn, Cu and Zn in cultivated soil [7,8]. Geographical directions, elevation and altitude greatly affect the soil fertility, runoff and erosion rate [9,10]. Level of rainfall, snowfall and temperature variation affects organic decomposition, which affects the accumulation of organic matter along elevation [11]. The change in micro-environment may affect soil properties. Hence there is a need to study and evaluate soil properties of the area in relation to altitude variation[12,13]. Therefore, the present study was planned to evaluate soil properties of the important agricultural soils along altitude gradients in cold high altitude in district Swat. Simultaneously the effect of past soil erosion will be studied on soil Physico-chemical properties which would be useful for the restoration of soil fertility of the study area.

2. Relationship of topography with soil properties
Soil Organic Carbon direct relation with altitude with correlation coefficient 0.826 and CaCO$_3$ shows harmful correlation decreasing with raise in altitude. Imran and Amanullah [14] investigated the changes in soil Physico-chemical properties diagonally three different elevations in the mountainous range known as the[15] at 1660-2133 meter. The results showed that the soil Physico-chemical properties of collected samples showed a positive correlation with the elevation grade. Soil pH showed small changes with the elevation grade. EC was lowest at 1804 m and highest at 1660 m with the rate of correlation coefficient -0.095. [16,17] studied the effect on soil properties, as a key sign in terms of soil degradation and sustainable land management in the natural ecosystem, the survey of soil physical and chemical parameters were very important [18,19]. The research meant to review slope aspect on soil feature. Soil samples were collected by completely randomized factorial design in four geographical directions and flat by three replications in two depths of 0-30 and 30-60 cm. The investigated variables were Total Nitrogen, Phosphorus, Potassium, pH, Saturated Percentage, Calcium Carbonate Equivalent, Fe and Soil Texture. The outcome shows that there was an important relationship in NPK whereas there was no significant relationship in K, pH, SP and TNV in, unlike aspects. [12,20] studied that, in high cold wasteland height climatic and topographical condition may affect the soil properties. To need of this agriculture soil were collected from diverse altitude viz. site I (10000- 11000 ft), site II (11000-12000 ft) and site III (>12000 ft) at Leh-Ladakh (cold desert high altitude region) in India. At site II the sand percentage was found more and reduce step by reduced step height [21]. To compare both sand and silt, the silt range was recorded more at the site I but increased with increased in height.

3. Soil bulk density and topography
Imran [22,23] recorded that soil physic-chemical properties slope. The main variation appears in the top, mid and bottom slope soil physic-chemical properties. At the top of the slope, the bulk density was calculated high followed by mid and then the bottom. Just like bulk density, the opposite condition was recorded for electrical conductivity, P, K, organic matter, clay contents, and salt from bottom to top slope. Soil A, B and C horizons were also notably diverse in their Physico-chemical properties. Horizon Ap had the highest bulk density and lower electrical conductivity, P, K, OM, clay, and salt contents compare to both B and C horizons. [24–26] studied to evaluate the physical properties of soils at various depths located in the Mardan SCARP area of Khyber Pakhtunkhwa
Province (Pakistan) during 2003-04. The analysis of variance indicated non-significant changes in sand, silt and clay fractions with cropping sequence, but showed significant changes in sand and clay with soil depth. Sand particles decreased while clay increased with increasing soil depth [27–29]. Soil permeability, leaching fraction and hydraulic conductivity, on the other hand, showed significant changes with cropping sequence and depth. Soil permeability and leaching fraction were greatest after maize than after or before wheat and both fractions increased with increasing depth. [30–32] evaluated that soil property on the growth of Haloxylon sp. in Segzi plain in the Eastern of Isfahan province (centre of Iran). Then the soil samplings of 0-30, 30-60, 60-90 and 90-120 cm depth were done. Plant physiological parameters, as well as plant height and top were considered. Soil physical and chemical characteristics such as soil texture, total nitrogen (TN), pH, electrical conductivity (EC), chloride ions (Cl) and sodium absorption ratio (SAR) were measured. These results showed that the EC, SAR, Cl, pH and the proportion of clay had a harmful effect on plant physiologic parameter. The fraction of sand and depth of hardpan from the soil surface had positive effects on plant parameters. Charan et al [33] studied that, soil physical and micromorphological properties response to skid machinery. The findings pertaining to bulk density are different in four positions and two soil depths. Soil porosity and soil saturated hydraulic conductivity also recorded difference like bulk density in all positions. Void and channel voids measured through picture Tool software showed a raise in the parameter.

4. Soil nutrients status and topography

[34,35] studied that, vegetable growing area of Peshawar soil physical and chemical properties significantly affected soil pH, organic matter (27) and (55%) in the medium in top soil sample. Total N was recorded deficient in 27 and (61%) in the medium. AB-DTPA extractable P was evaluated deficient in (27) and medium in (11%) sample in surface soil while it was found deficient in 33 and medium in 22% samples in subsurface soil. AB-DTPA extractable potassium was found in 44 medium and adequate in 55% samples in surface soil while it was found in 66 medium and adequate in 33% samples in subsurface soil. AB-DTPA extractable copper and manganese were found adequate in all the samples [36–38]. AB-DTPA extractable iron was found in 11 medium and adequate in 88% samples in surface and subsurface soil. AB-DTPA extractable zinc was found deficient in 33,11 medium and adequate in (55%) surface soil samples whereas found deficient in 44.16 and adequate in (38%) in sub soil surface. At the rate of fertilizers the area which was defiant in P, Zn and Fe could be recommended. [39,40] investigated the physical, chemical and pedogenetical soil properties of black pine forests at over 1400 meter altitude of Kazdagi mountainous uplands. Soil organic C % and Total N % decreased at A horizon while the pH decreased at Bw horizon with increased occurred in altitude. A positive and strong correlation was found among soil volume weight, fine soil, stoniness value. Elevations are most suitable for uppermost horizons [41,42]. The soil generation at 1550 m at Kazdagi mountainous land. [43] conducted a study during 2002-06 assess the status of soil texture of River Swat catchment area, also called Swat Valley. In total, 212 soil samples were collected twice (2005 and 2006) from 100 villages and were analyzed for soil texture. For water quality, river Swat water samples (three samples per month for the year 2006) were analyzed for suspended load. Slope was calculated in 100 different regions with the help of Global Positioning System (GPS). River Swat catchment is mountainous and the soil is mostly of sandy nature, presenting a fragile picture of soil. The average forest cover is 17% with a range varying from 5% in lower Valley to 25% in the upper parts. Besides, of forest land has been acquired as agricultural lands making the soil more susceptible to erosion. The seasonal fluctuation of the suspended load of River Swat during 2001-2004 was from 19 to 116 mg/l during low flow season (October -March) and from 137 and 692 mg/l in high flow season (April-September). The field observation shows that the rate of erosion was comparatively higher in those areas where the rainfall rate was less. The results provide sufficient encouragement of agroforestry through an awareness campaign and technical assistance for future studies.
5. Management of soil
[44,45] conducted a study to determine farmers’ perceptions of soil quality and common soil management practices that influenced soil fertility within farmers, fields in chukka and Gachoka divisions (Kenya). The study revealed that there were significant differences among soil fertility categories, using parametric techniques for key soil properties implying that there was a qualitative difference in the soils that were characterized as different by farmers [46–48]. Fertile soils had significantly higher pH, total organic carbon, exchangeable cations and available nitrogen. The first factor grouped calcium, magnesium and soil pH, while the second component comprised available nitrogen, organic carbon and total nitrogen. [49–51] Studied important land-use change recorded in the Mediterranean basin comprises the abandonment of agricultural lands due to economic and social changes, which is followed by significant impacts on soil erosion. Observed land abandonment may have positive or negative impacts on soil protection from erosion because fundamental ecosystem processes are influenced by changes in agricultural practices and soil resources management [52–54]. A field study was conducted for two years in order to monitor the change through time of natural resources such as soil and vegetation, following land abandonment, considering three land uses, cultivation, short-time abandonment and long-time abandonment [8,55,56]. Experimental plots were established on two specific slope gradients so that results could be comparable. When slope gradient is very steep (40%), soil sediment losses remain at the same high levels after cultivation abandonment because slope gradient is the main factor controlling soil erosion, although soil and vegetation properties are changing. [58, 69] [57,58] reported that Soil properties along with climatologically transacting the Southeast of Spain properties were studied. Three locations was selected, including semi and subhumid. The upper soil horizon aggregates stability related to soil properties were analyzed. An arid area the large aggregate of Z) 10. 10–5. 5–2 mm were reported. Soil structure, B.D and water retention was not affected. Aggregates 1–0.105 mm were positively correlated to medium, fine, very fine sand and silt fractions and to organic matter [59,60]. Aggregates 10.105 mm were positively correlated with organic matter and clay content. Small aggregate sizes Z1–0.105 and -0.105 mm had a significant effect on soil water retention and they are good indicator of soil degradation.[61,62] tested the statement that certain conditions of slope length and inclination and interactions between rainfall and runoff increased erosion rates in laboratory studies using standard sand and sandy loam soils [63,64]. The results indicated that the rainfall–runoff interaction was most pronounced on short lengths (1.2m) of the slope at intermediate (5%) inclinations. Tests conducted on slopes of 1.5, 2.0 and 2.5 m in length showed that greased erosion occurred on the 1.5 m slope. Different surface processes (runoff, rain splash or a combination) dominated under different conditions. Runoff was most sensitive to slope variation, becoming dominant on steep slopes and was least erosive on shallow slopes.[65,66] reported that the mineral composition (P, K, Ca, Mg, Na, Mn, Fe, Zn and Cu) in the grassland herbage of central Spain. Grass samples were taken on both the lower and upper parts of 30 slopes representative of such grasslands [67–69]. Slope position led to large differences in Na and Cu concentration, with Cu concentration lowest and Na concentration highest at the bottom of the slopes. For the other elements analyzed, the differences were lower and there was no variation in Zn and Mg during the study period the grass was adequate for the nutritional needs of livestock in K, Ca, Mn and Fe but potentially deficient in P, Na and Mg [70–72]. [73,74] examined the response of soil texture to soil erosion. They reported a low content of sand at knoll, shoulder, back slope, and found highest in the lowest position while at the front of the slope the sand content were slightly more. The clay content also showed a change in vice versa to sand while silt remains unchanged.

Organic manure generally has multiple advantages because of balanced supply of nutrients, including micronutrients, increased availability of soil nutrients due to increasing activity of soil microbial, decomposition of harmful components, improvements in the soil structure and root development, and increased access to soil water [75–84]. On the other hand, soil fertility is defined as the soil quality that provides the right amount of nutrients to grow specified plants or plants and the right balance for that growth [85–91]. On the other hand, soil organic matter is essential to crop production and sustainable soil fertility [92–99] [100–106].
6. Conclusions
Soil physico-chemical and biological properties influence soil suitability for crop growth. Organic manure typically has several advantages due to balanced nutrient supply, including micronutrients, increased soil nutrient availability due to increased soil microbial activity, decomposition of harmful components, improved soil structure and root growth, and increased access to soil water.

References
[1] Alloway B J 2013 Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability Environmental Pollution (Netherlands: Springer)
[2] Andraski B J and Lowery B 1992 Erosion effects on soil water storage, plant water uptake and corn growth J. Soil Sci. Soc. Am. 56 1911–9
[3] Basta N J, Ryan J A and Chaney R C 2005 Trace element chemistry in residual treated soil: Key concept in metal bioavailability J. Environ. Qual. 34 49–63
[4] Imran, Amanullah, Arif M, Shah Z and Bari A 2020 Soil application of Trichoderma and Peach (Prunus persica L.) residues possesses biocontrol potential for weeds and enhances growth and profitability of soybean (Glycine max) Sarhad J. Agric. 36 10–20
[5] Imran, Amanullah and Al-Tawah A R 2020 The productivity of subsequent wheat enhanced with residual carbon sources and phosphorus under improved irrigation system Commun. Soil Sci. Plant Anal. 51 1–9
[6] Imran, Amanullah, Khan A A and Bari A 2019 Production statistics and modern technology of maize cultivation in Khyber Pakhtunkhwa Pakistan Plant sci. Arc. 2 1–12
[7] Ali I, Khan A A, Imran, Inamullah and Khan A 2019 Humic acids and Nitrogen levels optimizing productivity of green gram (Vigna radiate L.) Russ. Agric. Sci. 45 43–7
[8] Karim S A and Imran 2019 Reduction in substrate moisture content reduce final yield of wheat Biomed. J. Sci. Tech. Res. 15 1–5
[9] Imran, Amanullah, Bari A and Ali R 2018 Peach sources, phosphorous and beneficial microbes enhance productivity of soybean Soybean Reserch 16 39–48
[10] Imran 2018 Climate change is threat toward agronomy (base of food, fiber system), and food security Food Nutr. J. 3 1–8
[11] Imran 2018 Physiological and morphological traits of agronomic crops influenced by climate change Mod Concep Dev Agrono 1 1–4
[12] Imran 2018 Ecological environmental variability influence growth and yield potential of rice under northern climatic scenario Russ. Agric. Sci. 44 18–24
[13] Imran 2018 Phosphorous fertilization influenced weeds attributes And phenological characteristics Of mungbean cultivars (Vigna radiata l.) Russ. Agric. Sci. 44 229–234
[14] Imran and Amanullah 2018 Global impact of climate change on water, soil resources and threat towards food security: Evidence from Pakistan [Review] Adv Plants Agric Res 8 350–355
[15] Imran 2018 Organic matter amendments improve soil health, productivity and profitability of maize and soybean Ann Rev Resear 1 555–564.
[16] Imran and Khan A A 2017 Canola yield and quality enhanced with sulphur fertilization Russ. Agric. Sci. 43 113–9
[17] Amanullah, Inamullah, Alkahtani J, S E M, Mona S, Alwahibi, A M, Imran and Khalid S 2020 Phosphorus and zinc fertilization improve productivity and profitability under rice-wheat cropping system AgronomyJournal 10 1–15
[18] Imran, Amanullah, Arif M, Shah Z and Bari A 2020 Integration of Peach (Prunus persica L.) residues, beneficial microbes and phosphorus enhance phenology, growth and yield of soybeanpp Russ. Agric. Sci. 46 223–230
[19] Imran, Jamal N, Alam A and Khan A A 2017 Grain yield, yield attributes of wheat and soil physio-chemical characteristics influenced by biochar, compost and inorganic fertilizer application Agri Res Tech 10 1–6
[20] Imran, Bari A, Ali R, Ahmad N, Ahmad Z, Khattak M I, Ali A, Ahmad F, Khan I and Naveed S
2017 Traditional rice farming accelerate CH4 & N2O emissions functioning as a stronger contributors of climate change Environ. Sci. J. Impact Factor 9 89–92

[21] Imran 2017 Climate change is a real fact confronting to agricultural productivity Int. J. Environ. Sci. Nat. Resour. 3 1–8

[22] Imran, Khan A A, Ullah I, Zada H, Ahmad F, Shah S T, Usman A and Ullah I 2015 Yield and yield attributes of rapeseed cultivars as influence by sulfur level under swat valley conditions J. Pure Appl. Biol. 4 296–301

[23] Imran, Naveed S, Khan A A and Khattak I 2015 Impact of phosphorus levels and seed rates on growth and yield of late sown maize on high elevation in Swat, Pakistan J. Agric. Res. 28 406–13

[24] Imran, Amanullah, Bari A, Khan H and Ali R 2019 Climatic variability and agronomic cropping pattern. Agronomic Production Technology (Amsterdam: Springer Book)

[25] Belanovic S, Cakmak D, Kadovic R, Beloica J, Perovic V, Alnaass N and Saljnikov E 2012 Availability of some trace elements (Pb, Cd, Cu and Zn) in relation to the properties of pasture soils in Stara Planina mountain Bull. Fac. For. 106 41–56

[26] Charan G, Bharti V K, Jadhav S E, Kumar S, Acharya S, Kumar P and Gogoi D 2013 Altitudinal variation in soil physico-chemical properties at Cold desert high altitude 13(2): 267–277. J. Soil Sci. 13 267–77

[27] Blake G R and Hartage K H 1986 Bulk density Method of Soil Analysis ed A Klute (Madison: Science Society of America) pp 363–82

[28] Boix-Fayos C, Calvo-Cases A, Imeson A C and Soto S 2001 Influence of soil properties on the aggregation of some Mediterranean soils and the use of aggregate size and stability as land degradation indicators Catena 44 47–67

[29] Brady N C and Weil R R 2002 The Nature and Properties of Soils (Upper Saddle river: Prentice Hall)

[30] Bowman W D, Cairns D M, Baron J S and Seasted T R 2002 Islands in the sky: Alpine and treeline ecosystems of the Rockies Rocky Mountain Futures: An Ecological Perspective ed J S Baron (Washington (DC): Island Press) pp 183–202

[31] Bromley P 1995 The effect of elevation Gain on soil Environ. Stud. 102

[32] Cassel D K and Nielsen D R 1986 Field capacity and availability water capacity Agronomy Methods of Soil Analysis ed A Clute (America: Agron) pp 901–24

[33] Cole V C, Paustian K, Elliott E T, Metherell A K, Ojima D S and Parton W J 1993 Analysis of agro ecosystem carbon pools Water Air Soil Pollut. 70 357–71

[34] Danielson R D and Sutherland P L 1986 Porosity Methods of Soil Analysis ed A Clute (USA: Agron) pp 443–61

[35] Dwivedi S K, Sharma V K and Bharadwaj V 2005 Status of available nutrients in soil of cold arid region of Ladakh J. Indian Soc. Soil Sci. 53 421–3

[36] Khan F, Hayat Z, Ahmad W, Ramzan M, Shah Z, Sharif M, Mian I A and Hanif M 2013 Effect of slope position on physico-chemical properties of eroded Soil. Soil Env. 32 22–8

[37] Feng Q, End K N and Cheng G 2002 Soil carbon in desertified land in relation to site characteristics Geoderma 106 21–43

[38] Frye W W 1987 The effects of soil erosion on crop productivity Agriculture Soil Loss (Processes, Policies and Prospects) ed J M Harlin and G M Berardi (USA: Westrien INC) pp 151–71

[39] Frye W W, Ebihar S A, Murdock L W and Blevins R L 1982 Soil erosion effects on properties and productivity of two Kentucky Soil Sci. Soc. Am. J. 46 1051–5

[40] Gardner W H 1986 Water content Methods of Soil analysis ed A Clute (USA: Agron) pp 383–411

[41] Garcia A B, Rodriguez B, Garcia N, Gaborcik V, Krajcovic and Zimkova M 1990 Mineral nutrients in pasture herbage of central western Spain. Soil grassland animal relationships General meeting of the European Grassland Banska Bystrica (Czechoslovakia: European
Grassland) pp 277–80
[42] Gee G W and Bauder J W 1986 Particle size analysis is part Methods of Soil Analysis ed A Clute (USA: Agron) pp 383–411
[43] Griffiths R P, Madritch M D and Swananson A K 2009 The effects of topography on the forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties For. Ecol. Manage. 257 1–7
[44] Gul H, Khattak R A, Muhammed D and Shah Z 2011 Physical properties of soils under Sub surface drainage system Sarhad J. Agric. 27 225–32
[45] Havelin J L and Soltanpour P N 1981 Evaluation of AB-DTPA soil test for iron and zinc Soil Sci. Soc. Am. J. 45 , 70–55
[46] Helburg G R, Wallen N C and Miller G A 1978 A century of soil development in soil derived from loess in Iowa Soil Sci. Soc. Am. J. 42 339–43
[47] Hussain F 1993 Effect of Land Scape Position and Fast Soil Erosion On Some Soil Properties and Environmental Degradation [Thesis]
[48] Kamalu C and Rickson R J 1994 The effect of slope length and inclination on the separate and combined actions of rainsplash and runoff (UK)
[49] Jobbagy E G and Jackson R B 2000 The vertical distribution of soil organic and its relation to climate and vegetation Ecol. Appl. 10 423–6
[50] Mairura F S, N M D, Mwanje J, Ramisch J J, Mbugua P K and Chainu J N 2007 Integrating scientific and farmer evaluation of soil quality indicators in Central Kenya. Geoderma 139 134–43
[51] Khan F, Ahmad W, Bhatti A U, Khattak R A and Shafiq M 2004 Effect of Soil erosion on chemical properties of some soil series in NWFP Pakistan Sci. Technol. Dev. Journals 23 31–4
[52] Kato T, Tang Y H, Gul S, Hiroto M, Du M Y, Li Y N and XQ Z 2006 Temperature and biomass influences on inter annual change in CO2 exchange in an alpine meadow on the Qinghai-Tibetan Plateau Glob. Chang. Biol 12 1285–98
[53] Khan F, Ahmad W, Bhatti A U and Khattak R A 2003 Effect of soil erosion on physical properties of some soil series in NWFP-Pakistan. Pakistan J. soil Sci. 22. 36–42
[54] Khresat S A and Qudah E A 2006 Formation and properties of aridic soils of Azraq Basin in northeastern Jordan J. Arid Environ. 64 116–36
[55] Kidanemariam A, Gebrekidan H, Mamo T and Kibret 2012 Impact of altitude and land use type on some physical and chemical of acidic soils in Tsegede Highlands, Northern Ethiopia J. Soil Sci. 2 223–33
[56] Koh M K and Sato K 1998 Rill erosion on land development area: practical studies on the mechanism of rill initiation and development Trans JSIDRE 135 25–32
[57] Miller M P, Singer M J and Nielson D R 1988 Spatial variability of wheat yield and soil Properties on complex hills Soil Sci. Soc. Am. J. 25 21–67.
[58] Koulouri M and Giourga C 2007 Land abandonment and slope gradient as key factors of Soil erosion in Mediterranean terraced lands Catena Catena 69 274–281
[59] Kumar M and Babel A L 2011 Available micronutrient status and their relationship with soil properties of Jhunjhunu Tehsil, District Jhunjhunu, Rajasthan, India J. Agric. Sci. 3 97–106
[60] Kumar S, Charan G, Barti V K, Srivastava S E and JadHAV R B 2013 Altitudinal variation in soil physical-chemical properties at cold desert high altitude J. Sci. Plant Nutr. 13 267–77
[61] Mairura F S, Mugendi D N, Mwanje J I, Ramisch J J, Mbugua P K and Chainu J N 2007 Integrating scientific and farmers’ evaluation of soil quality indicators in Central Kenya Geoderma 139 134–43
[62] Li W H and Zhou X M 1998 Ecosystems of Qinghai- Xizang (Tibetan) plateau and their influence on environments Guangdong Sci. Technol. Press 406 978–81
[63] Sharma V K, Dwivedi K S, Tripathi D and Ahmed Z 2006 Status of available major and
micronutrients in the soils of different blocks of Leh district of cold arid region of Ladakh in relation to soil characteristics. J. Indian Soc. Soil Sci. 54: 248–50

[65] Mclean E O 1982 Soil pH and lime requirement. Methods of soil Analysis ed R H Miller and D R Keeney (Agron) pp 209–23

[66] Mehdi A I, Bagheri S B, Kalhori and Khormali F 2011 Effect of compaction on physical and micromorphological properties of forest soils. J. Plant Sci. 3: 159–63

[67] Midkiff D V, Blevins W W and Frye R L 1985 Soil erosion effects on soil properties and crop yield in farmers fields in Kentucky during 1983-84. Am. Soc. Agron. Madison 8: 209

[68] Milivojevic J, Jakovljevic M D, Jelic M and Rakocевич L 2002 Investigation of methods for Fe, Mn and Zn solubility in the smonitzas of Serbia (Belgrade). J. Agric. Sci. 47: 9–18

[69] Mohammad N, Jan M R, Khan H and Ali A 2008 Status of soil texture and required associated soil conservation measure of river swat catchments area, Nwp, Pakistan. Sarhad Sarhad J. Agric. 24: 252–60

[70] Mojiri A, Jalalian A and Honarjoo N 2011 Effects of selected soil properties on growth of haloxylonsp. J. Anim. Plant Sci. 21: 686–91

[71] Nelson D W and Sommers L E 1982 Total carbon, organic carbon and organic matter. Methods of Soil Analysis ed R H Miller and D R Keeney (Wisconsin, USA: American Society of Agronomy) pp 539–77

[72] Nizami M M I, Zia M S and Saleem M 1997 Phosphorus requirements of maize under three tillage practices in different soil series in rainfed conditions. Pakistan J. Soil Sci. 18: 66–9

[73] Naseem W B 1998 Physico-Chemical Characteristics of Some Eroded Series of Rawalpindi Area [Thesis] (University Rawalpindi)

[74] Nelson R E 1982 Carbonate and gypsum. Method of soil Analysis ed R H Miller and D H Keeney (Madison: American Society of Agronomy) pp 181–98

[75] Turk M A and Tawaha A R M 2002 Impact of seeding rate, seeding date, rate and method of phosphorus application in faba bean (Vicia faba L. minor) in the absence of moisture stress. Biotechnol 6: 171–8

[76] Abu-Darwish M S, Abu-Dieyeh Z H, Mufeed B, Al-Tawaha A R M and Al-Dalain S Y A 2009 Trace element contents and essential oil yields from wild thyme plant (Thymus serpyllum L.) grown at different natural variable environments. J. Food Agric. Environ. 7: 920–4

[77] Turk M A, Tawaha A M and El-Shatnawi M K J 2003 Response of lentil (Lens culinaris Medik) to plant density, sowing date, phosphorus fertilization and ethephon application in the absence of moisture stress. J. Agron. Crop Sci. 189: 1–6

[78] Alu’datt M H, Rababah T, N A M, A A-T, Al-Tawaha A R, Gammoh S and Kubow S 2019 Herbal yield, nutritive composition, phenolic contents and antioxidant activity of purslane (Portulaca oleracea L.) grown in different soilless media in a closed system. Ind. Crops Prod. 141: 111746

[79] Al-Rifaee M O H D, Turk M A and Tawaha A R M 2004 Effect of seed size and plant population density on yield and yield components of local faba bean (Vicia faba L. Major). Int. J. Agric. Biol. 6: 294–9

[80] Nikus O, Turk M A and Al-Tawaha A M 2004 Yield response of sorghum (Sorghum bicolor L.) to manure supplemented with phosphate fertilizer under semi-arid Mediterranean conditions. Int. J. Agric. Biol. 6: 889–93

[81] Nikus O, Turk M A and Al-Tawaha A M 2004 Effect of manure supplemented with phosphate fertilizer on the fodder yield and quality of two sorghum cultivars (Sorghum bicolor L.) Biosci. Res. 1: 1–7

[82] Tawaha A M, Singh V P, Turk M A and Zheng W 2003 A review on growth, yield components and yield of barley as influenced by genotypes, herbicides and fertilizer application. Res. Crop 4: 1–9

[83] Seguin P, Zheng W, Souleimanouv W, Smith D L and Tawaha A M 2003 Effects of cultivars and fertilization on soybean isoflavone content. Can. J. Plant Sci. 84: 254
[84] Turk M A, Tawaha A M and Samara N 2003 Effects of seeding rate and date, and phosphorus application on growth and yield of norton vetch (Vicia narbonensis) Agronomie 23 1–4
[85] Turk M A, Tawaha A M, Taifor H, Al-Ghzawi A, Musallam I W, Maghaireh G A and Al-Omari Y I 2003 Two row barley response to plant density, date of seeding and rate and method of phosphorus application in the absence of moisture stress Asian J. Plant Sci. 2 180–3
[86] Turk M A, Tawaha A M, Samara N and Latifa N 2003 The response of six row barley (Hordeum vulgare L.) to nitrogen fertilizer application and weed control methods in the absence of moisture stress Pakistan J. Agron. 2 101–8
[87] Turk M A, Hameed K M, Aqel A M and Tawaha A M 2003 Nutritional status of durum wheat grown in soil supplemented with olive mill products Agrochimica 47 209–19
[88] Turk M A and Tawaha A M 2001 Influence of rate and method of phosphorus placement to Garlic (Allium sativum L.) in a Mediterranean environment J. Appl. Hortic. 3 115–6
[89] Tawaha A M and Turk M A 2002 Lentil (Lens culinaris Medic.) productivity as influenced by rate and method of phosphate placement in a Mediterranean environment Acta Agron. Hungarica 50 197–201
[90] Turk A M and Tawaha A M 2002 Impact of seeding rate, seeding date, rate and method of phosphorus application in faba (Vicia faba L. Minor) in the absence of moisture stress Biotechnol. Agron. Soc. Environ. 6 171–8
[91] Turk A M and Tawaha A M 2002 Response of winter wheat to applied n with or without ethrel spray under irrigation planted in semi-arid environments Asian J. Plant Sci. 1 464–466
[92] Kiyym M A A, Turk M and Tawaha A R 2007 Effect of plant density and nitrogen rate on essential oils of marjoram under mediterranean conditions Pak. J. Sci. Ind. Res. 50 383–8
[93] Hammed K, Turk M, Assaf T and Tawaha A M A L 2008 Effects of application of olive mill by-products on chickpea yield and their symbiosis with mycorhizal fungi under arid conditions Int J Plant Prod. 2 341–52
[94] Al-Kiyym M A, Turk M, Al-Mahmoud M and Al-Tawaha A R 2008 Effect of plant density and nitrogen rate on herbage yiels of marjoram under mediterranean conditions J. Am. J. Agric. Environ. Sci. 3 153–8
[95] Hani N B, Al-Ramamneh E A D, Haddad M, Al-Tawaha A R and Al-Satari Y 2019 The impact of cattle manure on the content of major minerals and nitrogen uptake from 15N isotope-labeled ammonium sulphate fertilizer in maize (Zea mays L.) plants Pakistan J. Bot. 51 185–9
[96] Amanullah, Khan N, Khan M I, Khalid S, Iqbal A and Al-Tawaha A M 2019 Wheat biomass and harvest index increases with integrated use of phosphorus, zinc and beneficial microbes under semi-arid climates J. Microbiol. Biotechnol. food Sci. 9 242–7
[97] Al-Taey D K, Al-Shareefi M J, Mijwel A K, Al-Tawaha A R and Al-Tawaha A R 2019 The beneficial effects of bio-fertilizers combinations and humic acid on growth, yield parameters and nitrogen content of broccoli grown under drip irrigation system Bulg. J. Agric. Sci. 25 959–66
[98] Khalid S, Khan H A, Arif M, Altawaha A R, Adnan M, Fahad S and Parmar B 2019 Organic matter management in cereals based system: Symbiosis for improving crop productivity and soil health Sustainable Agriculture Reviews 29 (Berlin: Springer) pp 67–72
[99] Singh B, Upadhyay A K, Al-Tawaha T W, Al-Tawaha A R and Sirajuddin S N 2020 Biofertilizer as a tool for soil fertility management in changing climate IOP Conf. Ser. Earth Environ. Sci. 492 012158
[100] Mahhadmeh I, Wahab P E M, Refat A, Youssef, Al Sultan W and Massadeh A 2018 Effect of water flow rate on quantity and quality of lettuce (Lactuca sativa L.) in nutrient film technique (NFT) under hydroponics conditions Bulgarian J. Agric. Sci. 24 791–798
[101] Aljutheri H W, Habeeb K H, Altaee K and Jawad F 2018 Effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat Biosci. Res. 15 3988–97
[102] Al-Ghzawi A L A, Al Khateeb W, Rjoub A, Al-Tawaha, A R M Musallam I and Al Sane K O 2019 Lead toxicity affects growth and biochemical content in various genotypes of barley
(Hordeum vulgare L.) *Bulg. J. Agric. Sci.* **25** 55–61

[103] Ananthi T, Amanullah M M and Al-Tawaha A R M S 2017 A review on maize-legume intercropping for enhancing the productivity and soil fertility for sustainable agriculture in India *Adv. Environ. Biol.* **11** 49–64

[104] Turk M A, Assaf T A, Hameed K M and Al-Tawaha A M 2006 Significance of mycorrhizae *World J. Agric. Sci.* **2** 16–20

[105] Al-Tawaha A R and Al-Tawaha A R M 2017 Response of soybean plants to exogenous application of yeast extract: Growth and chemical composition *Am. J. Sustain. Agric.* **11** 31–6

[106] Tawaha A R M, Jahan N, Odat N, Al-Ramamneh E A D, Al-Tawaha A R, Abu-Zaitoon Y, Alhawatema M, Amanullah A, Rauf A R A and Wedyan M 2020 Growth, yield and biochemical responses in barley to dap and chitosan application under water stress *J. Ecol. Eng.* **21** 86–93