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Development of Feed Legumes as Suitable Crops for the Drylands of Iran

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DARI

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Key words:
Iran, ICARDA Dryland agricultural production systems, ag, Feed legumes, *Lathyrus* spp., *Vicia* sp.

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Executive Summary

This Working Paper reviews the current knowledge on feed legumes development in drylands of Iran and presents the results of studies done by the Iran's Dryland Agricultural Research Institute (DARI) in different agro-climatic zones of the country. The study includes the existing technologies, and advocates policy, and institutional innovations that are needed to improve food security and livelihoods in dryland areas.

Iran aims to increase its productivity and stability of rainfed forage crops to ensure food security and improve rural livelihoods in its dryland areas. Government agencies, NGOs, policy makers, farmers in rainfed conditions and rural communities are the key beneficiaries and target audiences for the implementation of these policies.

For growing forage crops in the rainfed conditions a critical factor is the selection of suitable crop species and their varieties for hay production in different agro-ecological zones and soil conservation practices.

Growing of perennial feed legume crops in rangelands/slopes is an effective strategy to overcome different forms of land degradation in dryland areas. This approach contributes to improving the capability base of natural resources and enhances the productivity and sustainability of the existing agricultural systems.

Regarding forage and grain yields, considerable genetic variation exists in the germplasm of vetches (*Vicia* spp.) and grass pea (*Lathyrus* spp.) in different environments. In general, grass pea is suitable for drier environments whereas vetches such as *Vicia panonica* and *Vicia villosa* are more suitable for cold highlands because of their ability to tolerate cold stress.

1.Introduction

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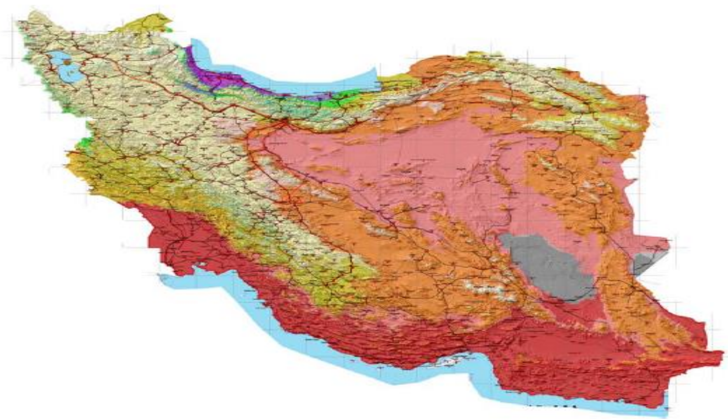
Dryland systems form a major part of Iranian agriculture. It plays an important role in enhancing food security, rural livelihood and environmental sustainability in the semi-arid areas. Iranian drylands are rich in agro-biodiversity and genetic resources which are increasingly threatened by overgrazing and urbanization. Highland areas are also the main source of water resources required for agriculture, industries and domestic use of increasing population living in the cities located at the downstream. However, drylands in Iran like in many countries did not receive due attention by policy makers and generally face acute poverty, low agricultural productivity, rapid rural migration, frequent drought and water shortages which are exacerbated by further degradation of natural resources and climate change.

The most poor and malnourished Iranian farmers live in the dryland areas and suffer from food insecurity. Many of these areas face severe land degradation, potentially undermining the productivity of these important ecosystems. Drylands are being degraded by the inappropriate land use practices and overgrazing. Increasing fuel prices are making agricultural inputs and operations more costly, reducing agricultural productivity, and increasing food insecurity. The global climate change would worsen the situation. Therefore, there is an urgent need to pay attention to improve production capacity in different agro-climatic zones and minimizing vulnerability in order to improve livelihoods for farmers in the drylands

1.1.Agro-Climatic Zones in Iran

The dryland areas of Iran are characterized by unpredictable weather and occurrence of frequent droughts and colds. The intensification of crop production in these areas needs to take into consideration the agro-climatic diversity, and land use patterns. In view of the diverse climates, an agro-climatic zone map is of vital importance to achieve this purpose.

On the basis of three criteria (moisture regime, winter type and summer type) adopted by the UNESCO (Appendix), 28 agro-climatic zones have been differentiated in Iran. Of them, six zones (arid-cool winter-warm summer, arid-cool winter-very warm summer, arid-mild winter-very warm summer, semi arid-cold winter-warm summer, semi arid-cool winter-warm summer, and semi arid-cold winter-mild summer) account for nearly 90% of Iran's area (see map legend).



COLOUR	Symbol	Moisture regime	Aridity Index	Temperature regime winter	Range_Win	Temperature regime summer	Range_Sum	No. grid cells	% of country	approx. area (sq.km)
	HA-M-VW	Hyper-arid	< 0.03	Mild	10° - 20°C	Very warm	> 30°C	55598	2.5%	41647
	HA-C-VW	Hyper-arid	< 0.03	Cool	0° - 10°C	Very warm	> 30°C	4944	0.2%	3687
	A-M-VW	Arid	0.03 - 0.2	Mild	10° - 20°C	Very warm	> 30°C	374998	16.7%	286822
	A-M-W	Arid	0.03 - 0.2	Mild	10° - 20°C	Warm	20° - 30°C	12534	0.6%	9705
	A-C-VW	Arid	0.03 - 0.2	Cool	0° - 10°C	Very warm	> 30°C	419665	18.7%	305814
	A-C-W	Arid	0.03 - 0.2	Cool	0° - 10°C	Warm	20° - 30°C	586071	26.2%	429257
	A-C-M	Arid	0.03 - 0.2	Cool	0° - 10°C	Mild	10° - 20°C	15	0.0%	11
	A-K-W	Arid	0.03 - 0.2	Cold	<= 0°C	Warm	20° - 30°C	50982	2.3%	36485
	A-K-M	Arid	0.03 - 0.2	Cold	<= 0°C	Mild	10° - 20°C	3680	0.2%	2758
	SA-M-VW	Semi-arid	0.2 - 0.5	Mild	10° - 20°C	Very warm	> 30°C	7350	0.3%	5380
	SA-C-VW	Semi-arid	0.2 - 0.5	Cool	0° - 10°C	Very warm	> 30°C	36238	1.6%	26454
	SA-C-W	Semi-arid	0.2 - 0.5	Cool	0° - 10°C	Warm	20° - 30°C	163123	7.3%	117526
	SA-C-M	Semi-arid	0.2 - 0.5	Cool	0° - 10°C	Mild	10° - 20°C	10	0.0%	8
	SA-K-W	Semi-arid	0.2 - 0.5	Cold	<= 0°C	Warm	20° - 30°C	385312	17.2%	271593
	SA-K-M	Semi-arid	0.2 - 0.5	Cold	<= 0°C	Mild	10° - 20°C	67638	3.0%	47039
	SH-C-VW	Sub-humid	0.5 - 0.75	Cool	0° - 10°C	Very warm	> 30°C	483	0.0%	344
	SH-C-W	Sub-humid	0.5 - 0.75	Cool	0° - 10°C	Warm	20° - 30°C	12000	0.5%	8380
	SH-K-W	Sub-humid	0.5 - 0.75	Cold	<= 0°C	Warm	20° - 30°C	17389	0.8%	12248
	SH-K-M	Sub-humid	0.5 - 0.75	Cold	<= 0°C	Mild	10° - 20°C	22140	1.0%	15529
	SH-K-C	Sub-humid	0.5 - 0.75	Cold	<= 0°C	Cool	0° - 10°C	48	0.0%	33
	H-C-W	Humid	0.75 - 1	Cool	0° - 10°C	Warm	20° - 30°C	6740	0.3%	4682
	H-K-W	Humid	0.75 - 1	Cold	<= 0°C	Warm	20° - 30°C	573	0.0%	395
	H-K-M	Humid	0.75 - 1	Cold	<= 0°C	Mild	10° - 20°C	598	0.0%	419
	H-K-C	Humid	0.75 - 1	Cold	<= 0°C	Cool	0° - 10°C	77	0.0%	53
	PH-C-W	Per-humid	> 1	Cool	0° - 10°C	Warm	20° - 30°C	12319	0.5%	8502
	PH-K-W	Per-humid	> 1	Cold	<= 0°C	Warm	20° - 30°C	70	0.0%	48
	PH-K-M	Per-humid	> 1	Cold	<= 0°C	Mild	10° - 20°C	11	0.0%	8
	PH-K-C	Per-humid	> 1	Cold	<= 0°C	Cool	0° - 10°C	27	0.0%	19

1.2. Dryland Agricultural Research Institute (DARI)

DARI was established in 1992 on a 500 ha farm at Maragheh and consists of 14 agricultural research stations located in different agro-ecological parts of the country. DARI coordinates all rainfed related researches in Iran and communicates with international institutions through its headquarters in Maragheh station. DARI's research agenda is to fulfill the mandate of increasing agricultural production in dryland areas using sustainable and environment friendly approaches while conserving the material resource base.

1.3. Feed legumes under rainfed conditions

Rainfall and temperature influence the relative importance of feed legume species. The introduction of vetches and grass pea to replace fallow after cereals increases the production of feed resources, and subsequently the carrying capacity of the land, in a sustainable manner. This also helps maintain the organic matter and nitrogen status of soil, improve the physical conditions of soil and break the pest and disease cycle. Thus, introduction of annual feed legumes in dryland cropping systems that are dominated by cereals is a profitable proposition for sustainable agriculture.

1.4. Factors limiting forage production in Iranian drylands

The inability to identify suitable legume cultivars that are adapted to local agro-ecological conditions explains the failure of adopting legume phase in some cropping systems. Low rainfall in early fall and rapid drop in temperatures along with severe frost in winter have restricted their adoption in the cold drylands of the country. Planting of legumes as spring crop is not advisable in cold drylands because of restricted plant growth, terminal drought and short crop season. Some of the factors affecting forage production in Iranian drylands are summarized as follows.

1. Abiotic stresses: cold, drought, terminal heat
2. Biotic stresses: Agrotis, Heliotis and crop specific diseases
3. Agronomic constraints: Poor soil preparation, low soil fertility, existing crop rotation, non-availability of suitable machineries, weeds, soil nutrient deficiency
4. Government policy: low market price, improper insurance policy, poor extension of research technologies in farmers' fields

1.5. Major Breeding Objectives at DARI

- Development of new cultivars with better yield and quality for different agro-ecological zones
- Integrated management of biotic (diseases and insect pests) and abiotic (environmental) stresses affecting potential productivity
- Development and refinement of improved package of production practices
- Research on plant nutrition

1.6. Research Activities

- Evaluation of international and national germplasm resources
- Generation of segregating populations
- Observation and yield trial nurseries
- Physiological and molecular aspects of tolerance to abiotic stresses
- On-farm trials with the participation of farmers, researchers and extension people

2. Plant Materials

2.1. Annual Legumes

2.1.1. *Vicia* species

Various species of the genus *Vicia* are traditionally used for feeding ruminants, particularly sheep, but they are practically unused for mono-gastric species in view of the toxicity and negative effect on growth. Bitter vetch (*V. ervilia*) must not exceed 25 percent of the ration in sheep and cattle feed. One-leaved vetch (*V. monanthos*) is more readily eaten by sheep, but refused by other types of livestock because of its slightly bitter taste. Birds, with the exception of pigeons, do not take it. The seed of *V. narbonensis* can be used as feed for cattle which accept it more readily than pigs and sheep, provided it is fed in ground form. Like common vetch (*V. sativa*), it has a slightly bitter taste which animals grow accustomed to, but which can be passed on into milk.

Extensive evaluation of winter annual legume crops (Lamei et al, 2012), resulted in identification of Hungarian vetch as the potential crop to provide greater biomass and nutritive value to livestock from May to June, a forage deficit period in cold region of Iran. Planting of Hungarian vetch as the second crop during fallow in winter may control soil erosion, meet the forage needs, control spring weed and recycle the wheat grains falls. Using this crop as green manure can help improve the soil fertility and meet partially the nitrogen requirement of the subsequent crop. Furthermore, agronomic practices (such as planting date, seed rate and mixed cropping with cereals) for growing this little known legume (Hungarian vetch) in the cold highland region in Iran hold tremendous scope to capture the potential benefits.

2.1.2. *Lathyrus* spp.

The genus *Lathyrus* includes about 150 species of annual and perennial herbaceous plants divided in 13 sections. However, only a few species are widely cultivated as food or fodder crops. The economically important species are *L. cicera* (chickling vetch) and *L. sativus* (grass pea). The annual grass pea, *L. sativus*, is a dual purpose crop cultivated as stock feed (Hanbury, 2000) and for human consumption (Kumar et al. 2011). It has a very hardy and penetrating root system and can be grown in a wide range of soil types, including very poor soil and heavy clays (Campbell, 1997). A relatively high biological nitrogen fixation rate, which assists in maintaining soil fertility, requiring few production inputs, allows this crop to be an important component in sustainable farming systems (Campbell et al., 1994; Peoples et al., 1995). Compared to other legumes, grass pea is resistant to many diseases and pests (Tiwari &Campbell, 1996).

Significant variation has been reported for forage yields among improved grass pea varieties under semi-arid conditions (Alizadeh and Kumar, 2012). Grass pea can grow successfully under the short-season environments as it can complete flowering within 50-60 days.Therefore, grass pea is recommended as summer fallow. Planting of grass pea with minimum tillage and life-saving irrigation just after the harvest of cereal crop could lead a volunteer mixture of cereals and legumes in order to enhance forage production (Alizadeh et al., 2013). It is a profitable alternative in summer fallow because it gives an additional crop at the end of growing season. It is especially recommended in the places/years that farmers could not produce enough forage during the main growing season.

2.1.3. Annual Medics

Annual medics (*Medicago spp*.) are leguminous crops closely related to alfalfa. They are originated from Mediterranean region; and Iran is one of its main centers of origin (Hanson, 1988). This crop completes its growth cycle in 2 - 8 months depending on the sowing time. Major advantages of annual medics can be summarized as quick hay production and feeding animals before harvesting alfalfa, controlling erosion and nitrogen fixation along with its possible application as green manure (Walsh et al., 2001).

We evaluated 362 accessions representing 16 species of annual medics collected from highlands of Iran by national gene bank at DARI for two years (2005-2007) in North-west Iran. The study showed a wide variation for winter survival among the annual medic accessions. Some of the accessions had the potential to survive as low as -25^{o}C temperature. *Medicago rigidula* showed the best performance when sown as autumn crop because of its good winter survival, biomass and seed yield. In addition, one accession of *M. rigidula* (51TN1851) showed frost tolerance and higher production potential for forage mass and seed and can be grown successfully under cold winter conditions in some drylands of Iran. In general, the potential of most medic accessions for dry matter production is limited by the short growing season under cold dryland conditions.

The dry matter of all medic accessions ranged between 200 and 2200 kg ha^{-1} with the average of 1100 kg ha^{-1}, which are not considerable amount compared with yield of some other feed legumes such as vetches and grass pea with average yield of about 5000 kg ha^{-1} in cold drylands (Alizadeh, 2008). The major priority of annual medics over vetches and grass pea is in their capability for regeneration that substantially depends on seed production. However, the amount of seed production of the majority of medics was not adequate for re-establishment in the subsequent year (Alizadeh and Sadeghzadeh, 2010).

2.2. Perennial legumes

Rangelands and slopes in the Iranian drylands are subjected to erosion extensively and can be managed using some perennial legumes such as alfalfa, sainfoin and other local legumes. Some local varieties of alfalfa (cv. Gharayonja), Sainfoin (Maragheh local) and landraces of milk vetch *(Astragalus sp.***)** were studied in typical slope (>45%). These varieties showed very good coverage in the second and third year to control erosion as well as forage production (Fig. 2).

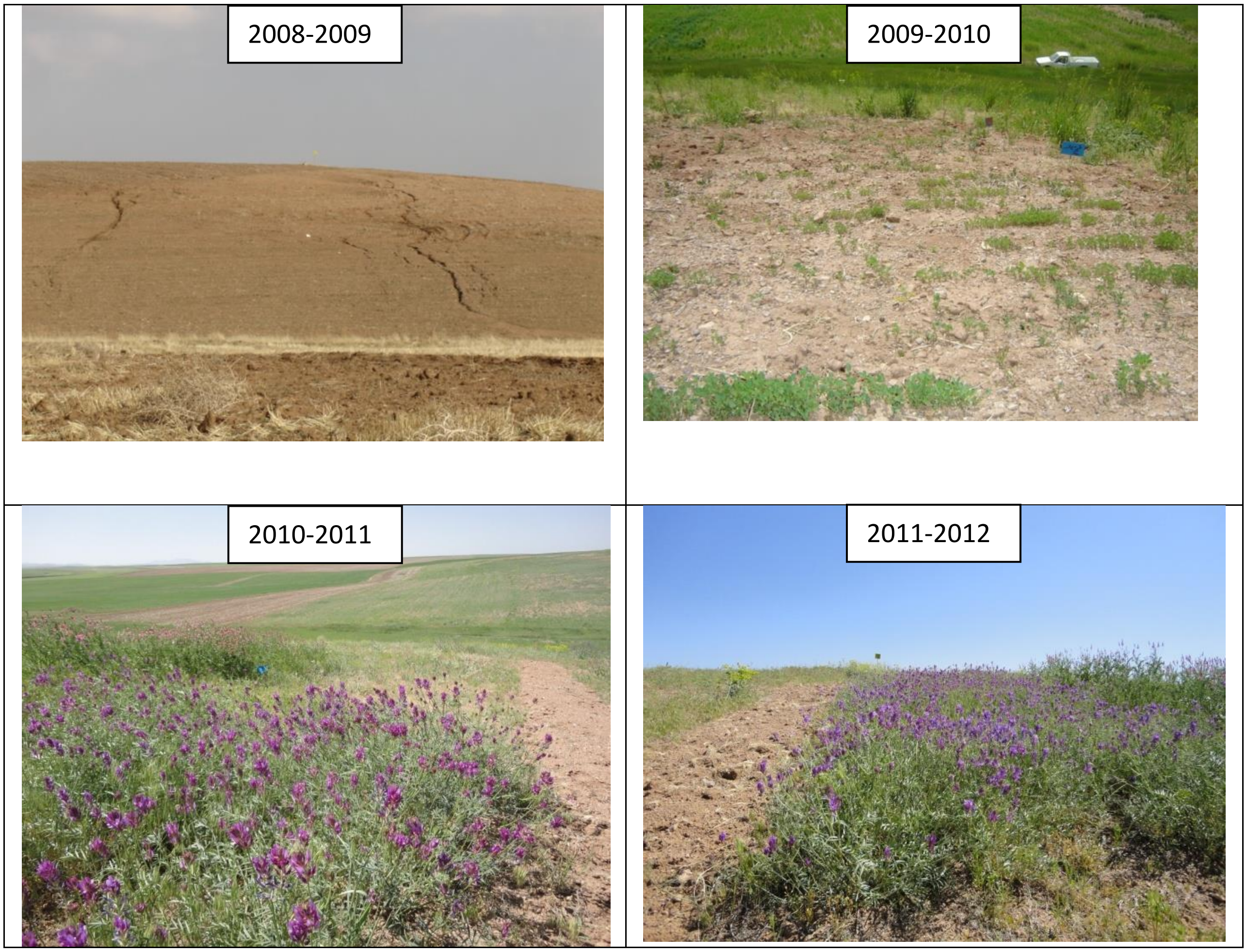


Fig 2. Perennial legumes in the slopes

3.Improved Cultivars - DARI's released forage cops

Released as: Maragheh (VD-2446) from *Vicia dasycarpa*

As spring crop in semi-cold and warm areas
Running-suitable for mix cropping

Released as: Golsefid (VP-2670) from *Vicia panonica*

Winter crop in Cold and Semi-cold areas
3500 kg/ha
erect

Under release: VS-2628 from *Vicia sativa*

Warm and Semi-arid areas
4372 kg/ha
erect

4.Production technologies

The experiments conducted on annual legumes over the past 12 years in the low and medium rainfall zones of Iran have indicated that late March is the best time to sow spring types in cold areas; and early October most suitable for winter planting in cold and semi cold areas. Delayed sowing reduces biomass production by as much as 50% in cold areas because of terminal drought. Sowing in the second half of October is the best time to harvest the best yield in the Iranian warm areas.

Vetch and grass pea species adapted to a range of soil types from sandy loams to heavy of moderate fertility. However, neutral soils are more suitable. Fertilizer requirement is similar to other pulses. In most situations, a starter dose of 10-12 kg nitrogen/ha at seeding stage and a maintenance application of 70-150 kg/ha super phosphate is all that is required. Annual legumes in rainfed areas are grown in rotation with cereals that regularly use a combination of fertilizers; this provides enough residual nutrients to maintain soil fertility for legumes growth.

Establishing an even, and healthy crop is the key to achieving consistently good performance of vetch species and grass pea. In general, low-density crops (25 plants/m^2 or less) compete poorly with weeds, are more attractive to aphids, and are difficult to harvest. The seed rate, in general, required to achieve this density depends on seed size, germination percentage and field establishment. Only about 60-75 percent of the seeds sown establishes in the field, depending on the conditions at sowing. It should be recognized that sowing deeper than 5-8 cm, can reduce emergence, particularly if the soil is susceptible to surface crusting.

Once established, there is no need of weed management when annual legumes are grown as forage crop. However, it is essential to control weeds if crop is grown for seed production. Annual legumes are tolerant to most grass-selective herbicides which could be used after emergence. Some general herbicides such as Paraquat are effective just after sowing in weedy lands as pre-emergence herbicide especially in spring seeding.

4.1. Mixed cropping of vetches and grass pea with barley

Mixed cropping of cereals with forage legumes can improve the quantity and quality of fodder compared to a pure cereal crop. In a legume-cereal mixture, the companion cereal provides structural support for the legume, improves light interception and facilitates mechanical harvest while the legume in mixture improves forage quality (Mpairwe et al., 2003). Other benefits of the mixture include greater uptake of water and nutrients, enhanced weed suppression and increased soil conservation (Vasilakoglou et al., 2005).

Bi-culturing of some annual feed legumes and barley was studied as a winter crop under Highlands conditions of Iran during 2009-2010 (Alizadeh and da silva, 2013). All legumes in the mixture survived winter while legumes alone, except Hungarian vetch, did not survive in the cold areas. The maximum fresh and dry forage yields (56 and 15 ton ha^{-1} respectively) were obtained from a mixture of smooth vetch and barley in provinces with mild winter and more than 400 mm of rainfall. The mixture of barley and smooth vetch resulted in the highest mean crude protein content (17%). Autumn seeding of smooth vetch cv. Maragheh and barley in a 1:1 ratio produced more than 2 ton ha^{-1} of dry biomass with good quality in the studied areas and thus could serve as an alternative cropping system after wheat/barley in cold and semi-cold drylands.

4.2.Conservation agriculture

Research activities at DARI have been focused mostly on impacts of conventional and conservation tillage, land use, cropping systems and improving soil fertility. Objectives are to improve sustainability of crop production and soil fertility quality and to transfer new findings and technologies for adoption by farmers.

Most of research activities related to conventional and conservation tillage systems (time, implement, depth, frequency), crop establishment (varieties, sowing date, method, rate), soil fertility (plant residual impact, soil analysis, fertilizer response, time of fertilizer application, etc.), integrated weed control (rotation, allelopathy, chemical, mechanical), mechanization of legume harvest (machinery, cropping systems management, etc.), and supplemental irrigation for dryland crops. The results indicated soil nitrogen from the forage rotation and plant residuals as a biological N source improved nitrogen availability for greater wheat grain production. Minimum tillage system with crop residue was effective for improvement of soil moisture contents. Introduction of forage crops in rotation increased soil fertility quality and forage production.

Sloppy lands are suitable for forage growth. It can be concluded that minimum tillage, appropriate rotation and plant residue improve soil quality and crop yields. Nitrogen sources from rotation and fertilizers are major influential factors for increasing crop production in dryland condition.

5.Conclusions

Annual and perennial feed legumes can be introduced for rangelands/slopes to increase forage production, overcome soil erosion and improve soil fertility in drylands. As a result, the capability base of natural resources could be improved, leading to enhancing the productivity and stability in agricultural systems.

Considerable variation existed in forage and grain yields of improved vetches (*Vicia* spp.) and grass pea (*Lathyrus* spp.) at different environments. In general, *Lathyrus* spp. are suited to drier climates than vetch species and some vetches such as *Vicia panonica* and *Vicia villosa* are more cold tolerant comparing grass pea and other vetch species. It was cleared that bi-culturing of vetches and grass pea with cereals could roughly double the forage production still with good quality in the dryland conditions.

3.Appendix

Categories of the UNESCO map of Arid Zones

Table 1. Moisture regime classes and their interpretation

Moisture regime	Aridity index	Interpretation[1]
Hyper-arid (HA)	<0.03	Very low and irregular rain which may fall in any season Inter-annual variability of rainfall can reach 100 percent Almost no perennial vegetation, except some bushes in river beds; annual plants can grow in good years Agriculture and grazing are generally impossible
Arid (A)	<0.2	Annual rainfall of 80-150 mm up to 200-350 mm Inter-annual rainfall variability 50-100 percent Scattered vegetation including bushes, small woody, succulent, thorny or leafless shrubs Very light pastoral use possible, but not rainfed agriculture
Semi-arid (SA)	<0.5	In summer rainfall areas: mean annual rainfall from 300- 400 mm to 700-800 mm In winter rainfall areas: mean annual rainfall from 200- 250 mm to 450-500 mm Inter-annual rainfall variability 25-50 percent Steppe zone with some savannas and tropical scrub Sometimes good grazing areas and rainfed agriculture is possible, although with great yield fluctuations due to great rainfall variability
Sub-humid (SH)	<0.75	Inter-annual rainfall variability is less than 25 percent
Humid (H)	<1	Includes tropical savanna, maquis and chaparral, temperate forests, steppes etc.
Per-humid (PH)	>1	Agriculture is the normal use

[1] Source: UNESCO, 1979

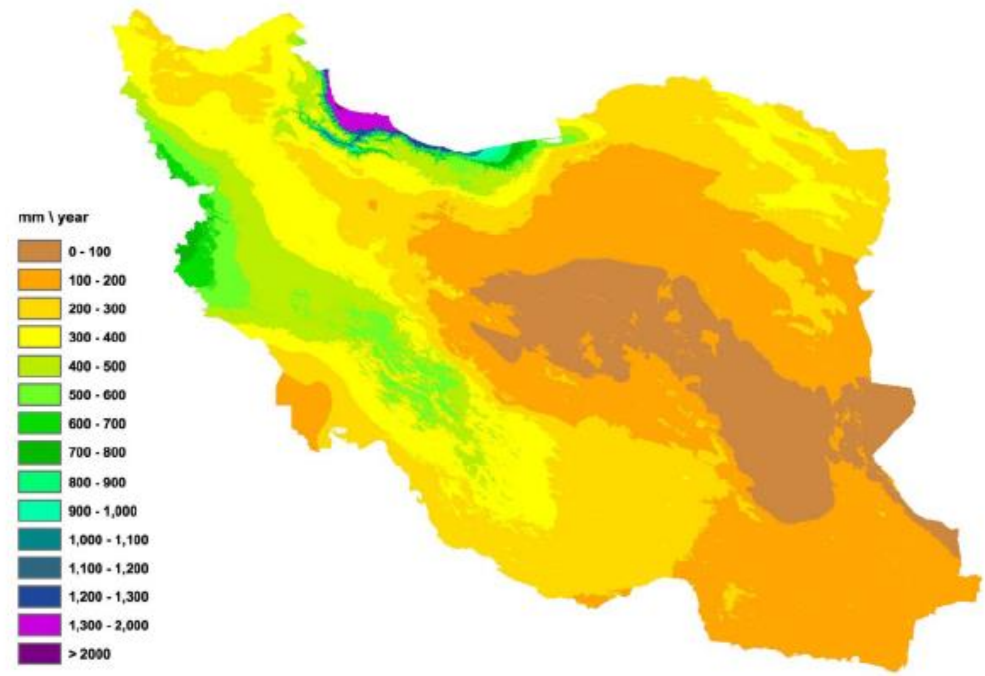
Table 2. Winter type classes and their interpretation

Winter type	Mean Tp. Coldest month	Interpretation: Winter rainfall areas	Interpretation: Summer rainfall areas
Warm (W)	> 20°C	N. A.	Continuous temperature delimited growing season
Mild (M)	> 10°C	Crop growth possible in winter; Limited need for rapid phenological development in spring;	Continuous temperature delimited growing season; Associated with tropical drylands; Lower development rate
Cool (C)	> 0°C	Limited crop growth; Need for rapid phenological development in spring; Need for efficiency of soil moisture abstraction	N. A.
Cold (K)	≤ 0°C	Above + need for cold tolerance for hibernating crops	N. A.

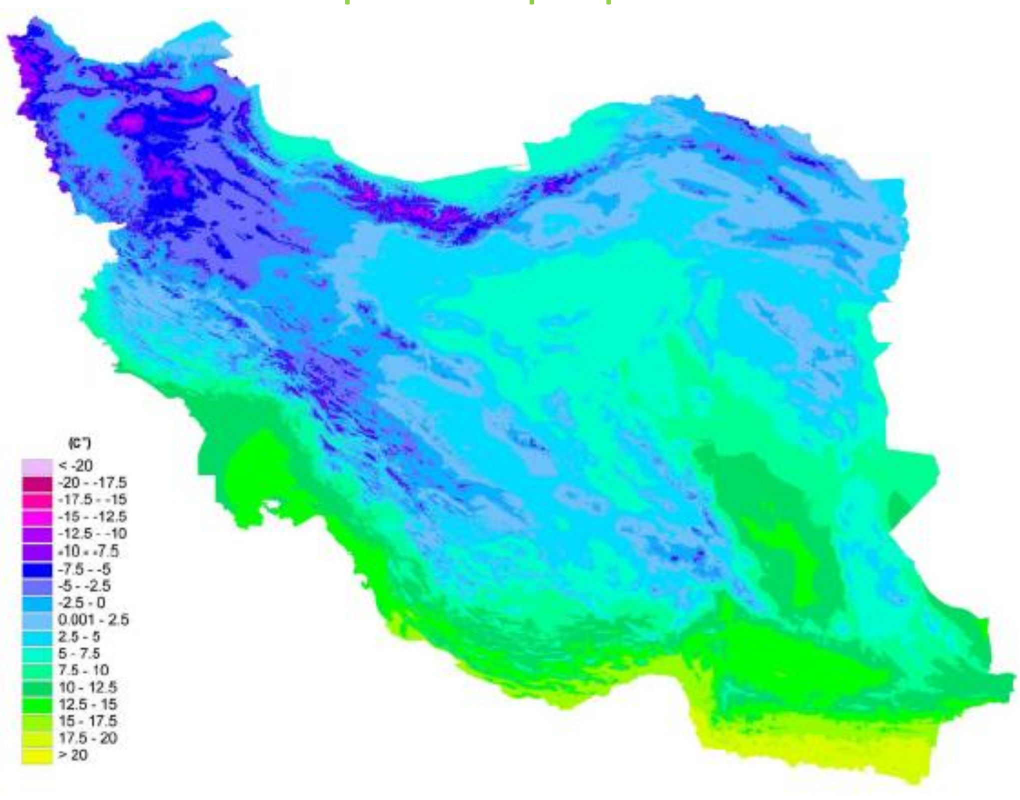
Table 3. Summer type classes and their interpretation

Summer type	Mean Tp. Warmest month	Interpretation: Winter rainfall areas	Interpretation: Summer rainfall areas
Very Warm (VW)	> 30°C	Total soil drying No carry-over to next season soil water	Development rate Evapotranspiration Crop water requirement
Warm (W)	> 20°C	Balance	
Mild (M)	> 10°C	Reduced potential biomass productivity	Restricted to tropical drylands; Need for rapid development rate under low temperature
Cool (C)	≤ 10°C	Strongly reduced potential biomass productivity	Restricted to high altitude sites; Low potential biomass productivity

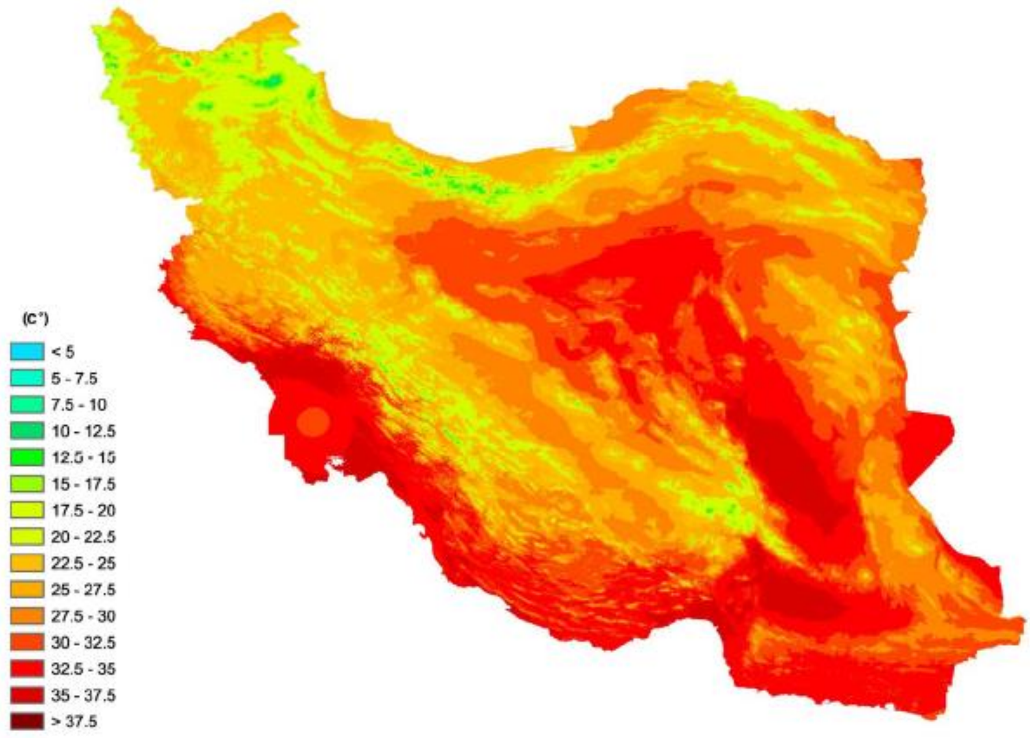
MAPS



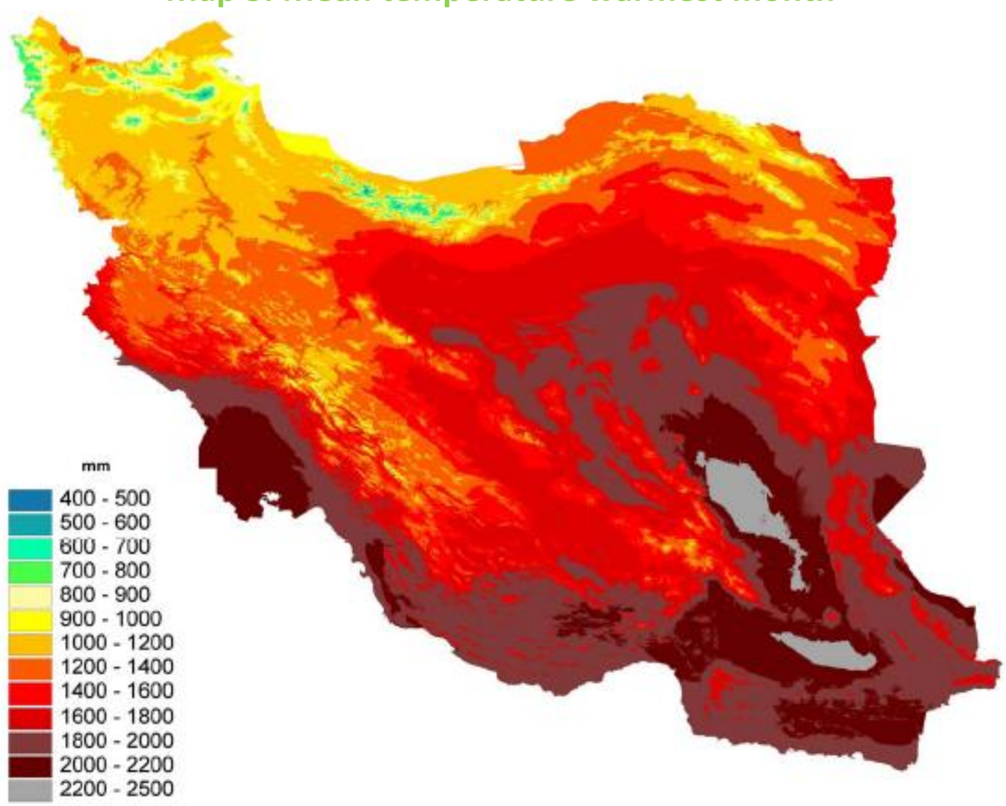
Map 1. Annual precipitation



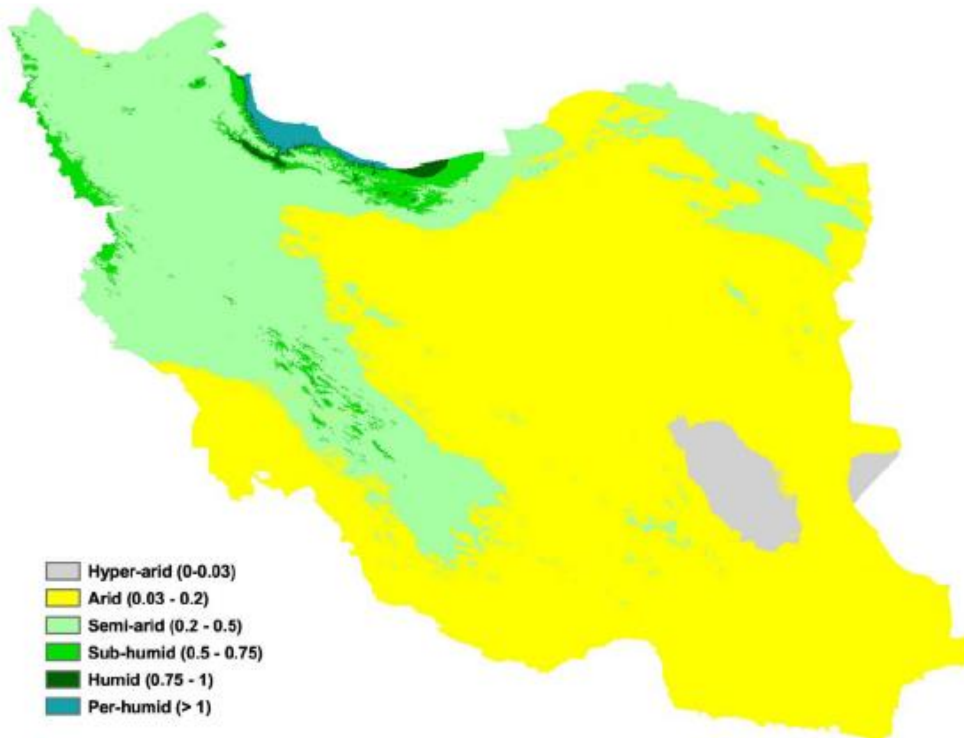
Map 2. Mean temperature coldest month



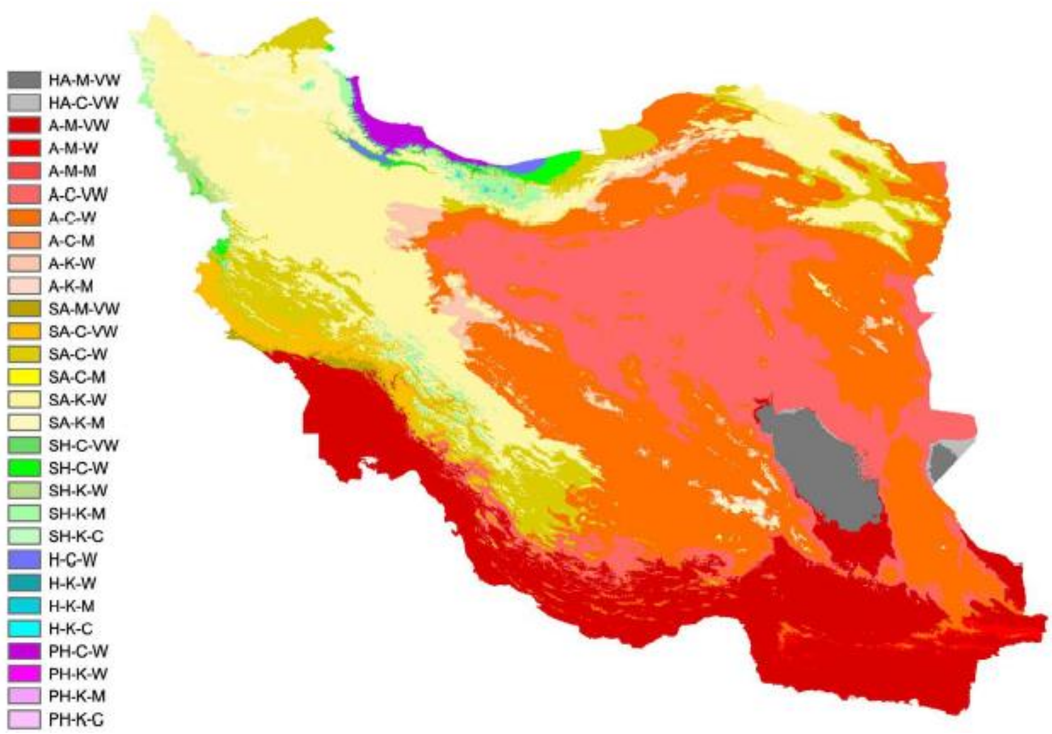
Map 3. Mean temperature warmest month



Map 4. Annual potential evapo-transpiration (Penman-Monteith)



Map 5. Aridity index



Map 6. Agro-climatic zones of Iran

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

CGIAR is a global research partnership that unites organizations engaged in research for sustainable development. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector. WWW.cgiar.org