Sustainable Irrigation Practices

Why irrigate?

The Central Highlands of Afghanistan are characterised by a harsh, dry climate, with annual precipitation ranging from 200 to 800 mm per year (see Annex 1: Precipitation and climate zones of Afghanistan). Precipitation mainly comes in late winter and in spring (see Annex 2: Rainfall distribution of Bamyan) and thus not at the time when the main crops are growing (see Annex 3: Cropping calendar Bamyan). Plants, however, need a continous water supply to grow and yield. If precipitation is below evapotranspiration, crops have to be irrigated. The water for irrigation can originate either from surface water (rivers and streams fed by glaciers) or from groundwater. The farming community has developed ancient and appropriate irrigation practices. For example, Afghanistan is famous for its traditional water management systems called "**karez**" - vertical shafts connected by gently-sloping tunnels, which use gravity to deliver underground water to the surface. The advantage of this traditional system is clearly the reduced loss of water to evaporation. Karez systems were used throughout Afghanistan to supply groundwater for irrigation (USDA&UC Davis, 2013). Indigenous practices and skills - ranging from a sophisticated infrastructure such as a karez to the practical skills of an individual farmer, such as breaking the water flow into a furrow by placing a thorny branch at the beginning of the furrow – are therefore always the point of departure for discussions about sustainable irrigation practices. Presently, 98% of Afghanistan's water resources are used for irrigation and livestock in agriculture (USDA&UC Davis, 2013). Population growth and climate change are increasing the pressure on these water resources, making it crucially important to use of the available water resources efficiently. In terms of efficient irrigation this means: more crop per drop.

Water is vital for plant growth

Water plays a vital function in photosynthesis and the chemical processes within the plant. A plant takes up water by its roots, and looses water during photosynthesis through the leaves. This process is known as **transpiration**. The same happens to water on the soil surface and excess water on the plants. This process is called **evaporation**. Evaporation is highest in dry and warm climate zones and is even higher in windy areas. The water needs of a crop thus consist of transpiration and evaporation - known as **evapotranspiration** - as presented in Figure 1. (ILRI, 2009)

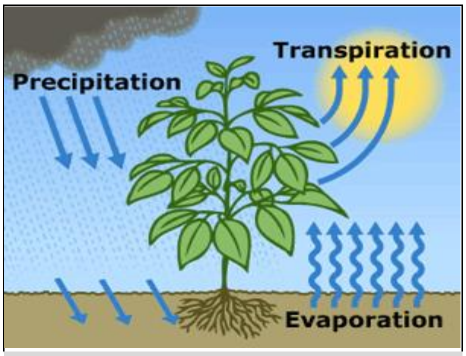


Figure 1: Water evapotranspiration, including evaporation from the soil and transpiration from plants (http://water.usgs.gov)

Crops' water requirements vary. In a semi-arid climate it is important to select crops that can deal with the limited amount of water. What is more, crops show varying sensitivity to drought, i.e. different degrees of drought tolerance. Table 1 summarises the water needs and sensitivity to drought of various crops cultivated in the Central Highlands of Afghanistan.

There are also differences *within* one crop. Some crop varieties - of potatoes, for example - need less water and are more drought-tolerant than others. Varietal selection therefore plays an important role if water is short.

The crop's water requirement also varies during the vegetation phases of a crop. The vegetation phases are divided into the:

1. Initial stage (germination)
2. Crop development stage
3. Mid-season stage (including flowering and yield formation)
4. Late-season stage (including ripening and harvest)

Generally speaking, the mid-season stage is the most sensitive to water shortages (see Figure 2). This is because it is the period when the crop's water needs are at their peak. A water shortage during this stage has a pronounced negative effect on the yield (ILRI, 2009).

To sum up: the water requirement depends on the crop itself, the crop variety and its development stage, and it varies over the crop's vegetation phases.

Table 1: Net crop water requirements (globally) (USDA&UC Davis, 2013)

Crop	Crop water need (mm/per growing season)	Sensitivity to drought
Wheat, Barley	450-650	Low-medium
Potato	500-700	High
Cabbage	350-500	Medium-high
Onion	350-500	Medium-high
Tomato	400-800	Medium-high
Alfalfa	800-1600	Low-medium
Sainfoin[1]	300 and more	Low

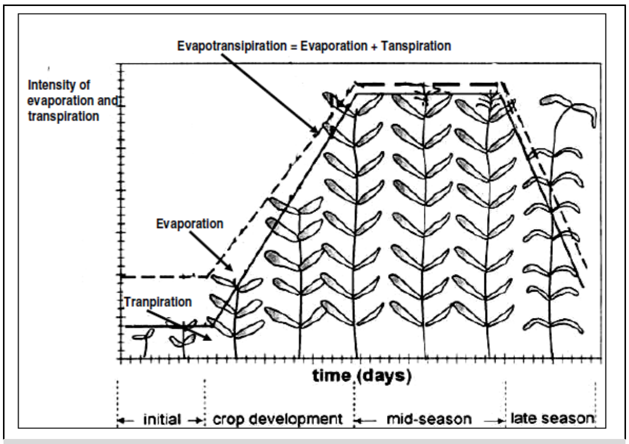


Figure 2: Evapotranspiration curve during the different vegetation phases (FAO, 1985)

In a dry climate such as Central Highlands of Afghanistan, crop water needs are higher than global net crop water requirements, and depend a great deal on temperature. The higher the temperature, the higher the crop water requirements.

Soil – plant - water

The properties of the soil and the crop itself affect the movement and use of water. The soil provides the space for water, which is taken up by plants through their roots. Water uptake is essential for plant growth, because the water contains important nutrients (ILRI, 2009). It is important that irrigation water is absorbed by the soil and not lost as runoff or through evaporation or percolation (in case of over-irrigation). This refers to the soil´s infiltration capacity. Bare soil with an even surface, espacially on sloping land, shows high water loss and low infiltration capacity (ILEIA, 2010). Infiltration capacity depends on the soil itself, as well as on the cover and type of vegetation. One other big challenge is to retain the moisture within the soil. In semi-arid areas like the Central Highlands of Afghanistan, **soil moisture** buffers and ensures water availability to plants even in the absence of rainfall. Soil moisture depends very much on the soil properties. Clays have the highest moisture retention capacity, while sandy soils have the lowest. Soil organic matter improves soil moisture retention capacity. The use of organic fertilisers (farmyard manure, compost, etc.) is especially important for improving soil moisture and reducing the need for irrigation in semi-arid areas. Cultivation practices such as mulching can also improve soil moisture (ILEIA, 2010).
A simple test can be performed to assess soil moisture in the field. Watch this video:
http://afghanag.ucdavis.edu/natural-resource-management/soil-topics/soil-videos/irrigation-by-feel-video

Sustainable irrigation

The (net) irrigation water needs of a certain crop are normally the difference between the crop's water requirement and the amount of rainfall that can be used by the crop (the effective rainfall). The irrigation schedule indicates how much irrigation water has to be given to a crop, and how often it has to be irrigated (ILRI, 2009).

Box 1: Main irrigation rules

- Provide right amount of water
- Provide the water at the right time
- Avoid erosion through irrigation

It is also important to select the most suitable irrigation technique. The most appropriate irrgation technique is the one that suits best local conditions and crop water requirements. (USDA&UC Davis, 2013) Furthermore, keep in mind that too much irrigation can also have a negative effect on plant growth, as most crops cannot deal with waterlogged situations. When there is over-irrigation, excess water runs off (on the surface or sub-surface), and nutrients are washed out from the soil.

Moreover, irrigation always also includes a social question, namely the organisation around water delivery for irrigation.

[1] Sainfoin: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq14389

Irrigation techniques

There are a number of irrigation techniques that are suited to the Central Highlands of Afghanistan. However, before choosing an irrigation technique always consider (USDA&UC Davis, 2013):

1. Water availability (source, distance, quantity and quality)
2. Local conditions (soil type, infiltration capacity, land topography, climate, labour availability)
3. Crop (water requirement, rooting depth, market value)
4. Resources (labour, electricity, fuel, spare parts)
5. Cost (installation, operation and mantainance, benefits)

Table 3 on the next page provides a short overview of selected irrigation techniques that are of relevance in the Central Highlands. More comprehensive sets of irrigation techniques are available from sources mentioned in the box "Further reading".

Organising irrigation

Particularly in situations where water is scarce, the delivery of in-time irrigation is as much a social question as a technical issue. In any given watershed, most farmers need water at the same time. How much water is available downstream depends on how much water has been used upstream. In small irrigation units the water allocation often works well by following customary rights (e.g. the amount of water and the timing of water allocation is linked to land titles). The water users in larger systems need to get organised. The water law in Afghanistan foresees coordination and service delivery units at several levels, from River Basin Councils to Sub-river Basin Councils and Water User Associations or Irrigation Associations. The law defines **Water User Associations** as a "voluntary assembly of real and legal persons (...) with the objectives of meeting social, economic and vocational use of water". If they are to supply irrigation water in an equitable and efficient manner Water User Associations need to be managed properly, according to the principles of good governance (transparency, efficient service delivery (= irrigation, participatory decision-making, accountability) and to have functioning conflict resolution mechanisms). Following the lines of an ancient system of farmer-elected "water masters" (***mirab***) according to the law the Water User Associations may delegate the responsibility for the managementand distribution of water rights to a "head water master" (*mirab bashi*) or "water master" (*mirab*) who are designated by the irrigation associations. Water users are expected to contribute free labour for the maintenance of the irrigation system. While the water law stipulates that in principle the use of water is free, service providers (such as Water User Associations) may charge the users a fee for delivery, storage, transmission, diversion, treatment, operation and maintenance of the water supply. This is important, since the construction, maintenance and management of irrigation infrastructure involves recurrent costs that need to be covered in a sustainable manner (Water law, USDA&UC Davis, 2013).

Table 2: Comparison between WUA and *mirab* systems

Mirab	Water User Association WUA
• Selected • No link to MAIL • Oral regulation • Volunteering • Payment in kind • No account keeping • Traditional water distribution plan • Conflict resolution by elders	• Elected board • Linked with MAIL • Written regulation • Membership fee • Service tax • Payment in cash or kind • Account-keeping • Formal water distribution plan • Conflict resolution by WUA

Further readings and references

- FAO, 1985: Irrigation Water Management: Training Manual No. 1 – Introduction to irrigation, available at: http://www.fao.org/docrep/r4082e/r4082e00.htm#Contents
- FAO, 1989: Guidelines for designing and evaluating surface irrigation systems, available at: http://www.fao.org/docrep/T0231E/t0231e03.htm#1.2.6%20crops
- ILEIA, 2010: Learning AgriCultures Module 2, Soil and water systems, available at http://www.agriculturesnetwork.org/resources/learning/mod2
- ILRI, 2009: Training manual on agriculture water management, available at: http://cgspace.cgiar.org/handle/10568/80
- Sustainable Sanitation and Water Management Toolbox, available at: http://www.sswm.info/
- USDA&UC Davis, 2013: Afghan Agriculture Portal, available at: http://afghanag.ucdavis.edu/

Table 3: Irrigation techniques

Picture	Description	Efficiency	Crops	Link
SURFACE	Include furrow, basin and border irrigation, see below:			http://www.sswm.info/category/implementation-tools/water-use/hardware/optimisation-water-use-agriculture/surface-irrigati
	**Furrow** Involves running water in “furrows” between plant rows or raised beds. Water moves from the furrow into the crop root zone (USDA&UC Davis, 2013)	Less efficent than all others	All type of crops, including fruit trees	Video: https://www.youtube.com/watch?v=rlCB_FK8sbE
	**Baisin** The field is leveled and surrounded by earth banks. The water is applied to the entire basin respective field.	Less efficent than all others		
SPRINKLER				
	**Sprinklers** Pipes with sprinkler heads that sprinkle water. Different types are used of the same system.		High value cash crops: vegetables and fruit trees	http://www.sswm.info/category/implementation-tools/water-use/hardware/optimisation-water-use-agriculture/sprinkler-irriga
MICRO				
	**Drip irrigation** Invovles a set of pipes with holes, where water drops slowly to the root zone of plants. This technique is water saving, but there is a risk of salinization if the soil is not “washed” at least once a year.	High cost systems up to 90%, low-cost system approx. 70%	High value cash crops: vegetables and fruit trees, suitable to irrigate individual plants	http://www.sswm.info/category/implementation-tools/water-use/hardware/optimisation-water-use-agriculture/drip-irrigation Video: http://www.youtube.com/watch?v=Ui66C0733DU
MANUAL				
	**Irrigation by Hand** Simple but effective irrigation method, including: • Watering cans • Pitcher irrigation • Bottle irrigation • Porous pipes		Home-gardens: vegetables	http://www.sswm.info/category/implementation-tools/water-use/hardware/optimisation-water-use-agriculture/manual-irrigatio

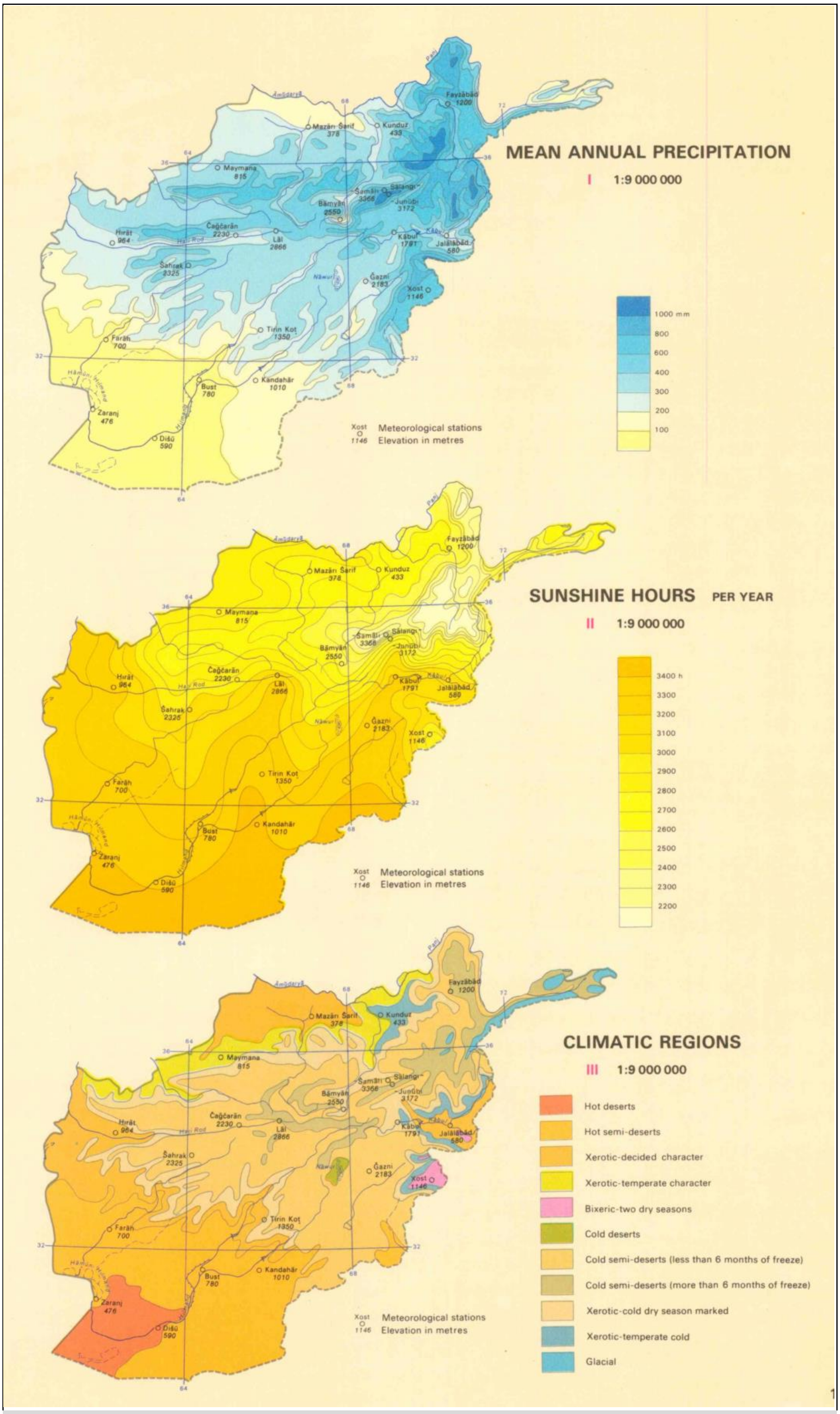
Author(s): Peter Schmidt and Tina Roner, April 2014

This publication has been made possible through financial support of Swiss Agency for Development and Cooperation SDC. The content, however, is the sole responsibility of HELVETAS Swiss Intercooperation.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

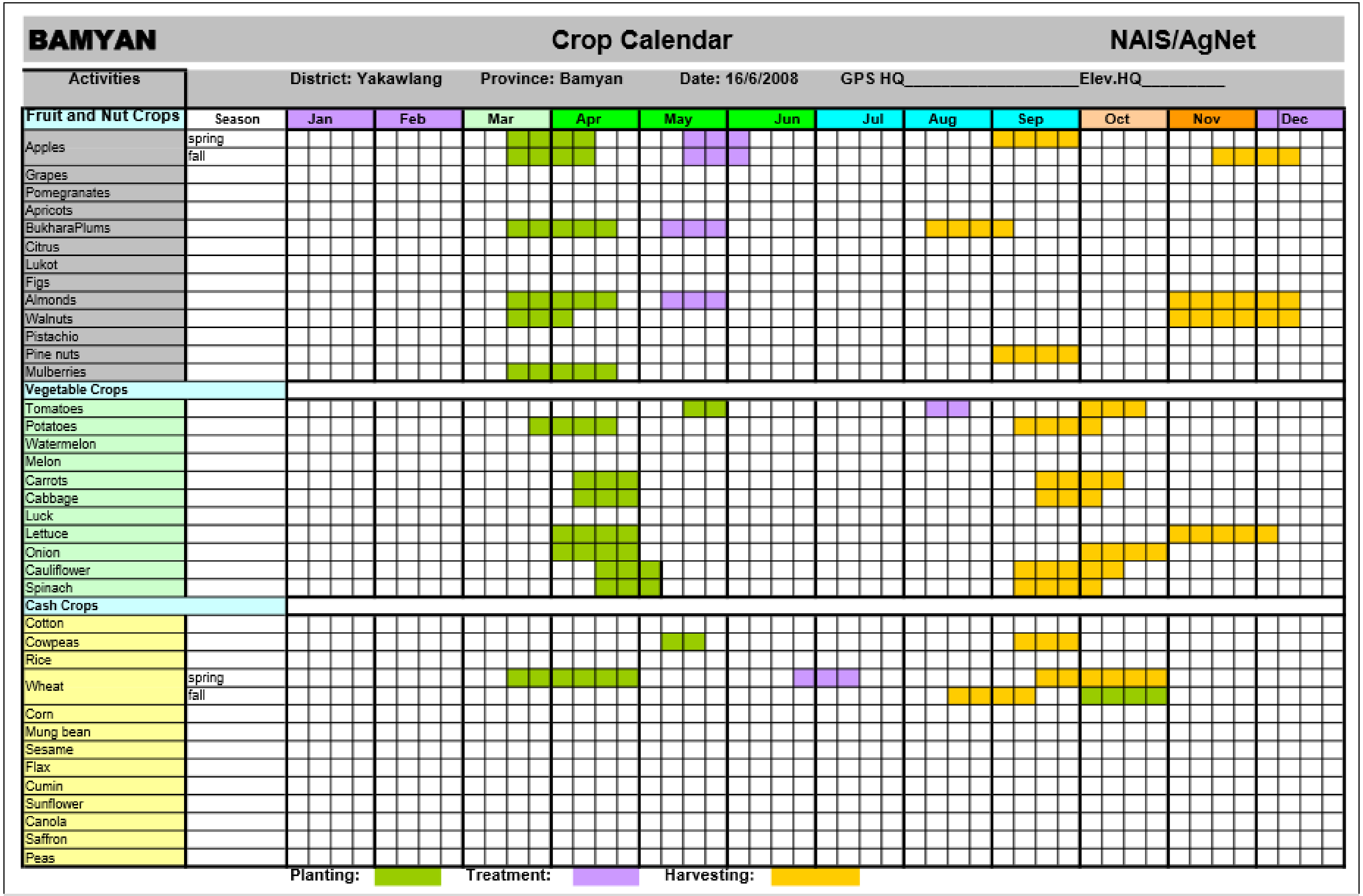
Annexes



Annex 1: Climate and annual precipitation in Afghanistan
(Source: http://www.aims.org.af/maps/national/national_atlas/07_precipitation.jpg)

Climate data for Bamyan [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	12.0 (53.6)	12.5 (54.5)	20.6 (69.1)	28.7 (83.7)	29.4 (84.9)	31.2 (88.2)	33.2 (91.8)	32.2 (90)	31.4 (88.5)	26.2 (79.2)	20.6 (69.1)	13.0 (55.4)	33.2 (91.8)
Average high °C (°F)	1.0 (33.8)	2.0 (35.6)	7.9 (46.2)	15.6 (60.1)	19.9 (67.8)	24.1 (75.4)	26.3 (79.3)	26.1 (79)	22.9 (73.2)	17.4 (63.3)	11.0 (51.8)	5.1 (41.2)	14.94 (58.89)
Daily mean °C (°F)	−6.4 (20.5)	−4.8 (23.4)	1.4 (34.5)	8.6 (47.5)	12.4 (54.3)	16.3 (61.3)	18.4 (65.1)	17.4 (63.3)	12.8 (55)	7.8 (46)	1.6 (34.9)	−2.8 (27)	6.89 (44.4)
Average low °C (°F)	−10.1 (13.8)	−6.1 (21)	−3.8 (25.2)	2.9 (37.2)	5.7 (42.3)	8.5 (47.3)	10.0 (50)	8.8 (47.8)	4.2 (39.6)	0.0 (32)	−4.9 (23.2)	−8.6 (16.5)	0.55 (32.99)
Record low °C (°F)	−30.5 (−22.9)	−28.4 (−19.1)	−21.2 (−6.2)	−6.5 (20.3)	−2.5 (27.5)	0.6 (33.1)	5.4 (41.7)	3.0 (37.4)	−2.6 (27.3)	−7.9 (17.8)	−14.5 (5.9)	−25 (−13)	−30.5 (−22.9)
Precipitation mm (inches)	8.3 (0.327)	15.7 (0.618)	27.4 (1.079)	29.8 (1.173)	26.0 (1.024)	5.7 (0.224)	1.0 (0.039)	0.0 (0)	3.1 (0.122)	4.2 (0.165)	7.5 (0.295)	4.3 (0.169)	133 (5.235)
Avg. rainy days	0	0	2	7	6	1	1	0	0	2	2	0	21
Avg. snowy days	5	7	6	2	0	0	0	0	0	0	1	3	24
% humidity	43	54	52	52	52	46	45	45	43	44	48	52	48
Mean monthly sunshine hours	196.7	174.6	210.7	239.4	no data	356.9	372.9	357.8	325.3	276.7	245.5	198.0	—
Source #1: Hong Kong Observatory[6]													
Source #2: NOAA (1960-1983)[7]													

Annex 2: Climate and rainfall distribution in Bamyan
(Source: http://en.wikipedia.org/wiki/Bamyan)



Annex 3: Cropping Calender Bamyan
(Source: http://afghanag.ucdavis.edu/country-info/Province-agriculture-profiles/cropping-calendars-1/IS_Crop_Calendar_Bamyan.pdf)