Water Harvesting Research, 2017, 2(1): 37-42
DOI: 10.22077/jwhr.2017.594
www.jwhr.birjand.ac.ir
P-ISSN: 2476-6976, E-ISSN: 2476-7603

Bandsar agriculture: indigenous runoff-harvesting &climate change resilience in Iranian dry lands

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Received: 5 March 2017 / Accepted: 21 June 2017

Abstract

Iranians have a very long history of water harvesting to address water scarcity and the consequences of frequent droughts. Among these strategies, *Bandsar* is a wide spread indigenous practice, which has been utilized in the central and the southern part of Khorasan province (the northeast Iran). Bandsar in Persian means a series of consecutive bands, berms, levees, or dikes. A Bandsar consists of a series of levees constructed along contour lines and adjacent to an ephemeral stream in a way that occasional floodwater flows can be diverted from the stream into the field(s) of the Bandsar system, to temporarily store the water on the upstream side of the levees. Water gradually penetrates into the soil profile and the accumulated moisture can be used for an appropriate cultivation. Bandsar agriculture has been found to be very unique and sustainable with regards to several key factors such as owners' participation, land-use, and water resource management. In this regard, a field survey was conducted in the suburbs of Sabzevar (57^{o} 4'E, 36^{o} 12'N), which are widely covered with Bandsars, some of which are still being used in the present time. Bandsar's components, construction method, operation, and maintenance have been studied and summarized here according to the information gathered from field observations and face to face interviews with some of the most experienced Bandsar owners.

Keywords: *Bansdar, Floodwater, Runoff, Agriculture, Indigenous Knowledge.*

1. Introduction

Floodwater irrigation has been practiced in most of arid and semi-arid zones of Iran and many other countries with similar climate (Ghoddousi, 1999). Among the many kinds of methods used worldwide, Bandsar is the most specific type of floodwater harvesting, which has been utilized in the eastern parts of Iran. Bandsar is composed of several earthen levees constructed successively along level contour lines and next to a seasonal stream from which floodwater flows can be diverted via a conveying channel into the fields of the Bandsar (Figures 1 through 6). The incoming water spreads behind the levees, so that the resulting backwater makes the soil moisture to increase to a sufficient level for sustaining compatible cultivation.

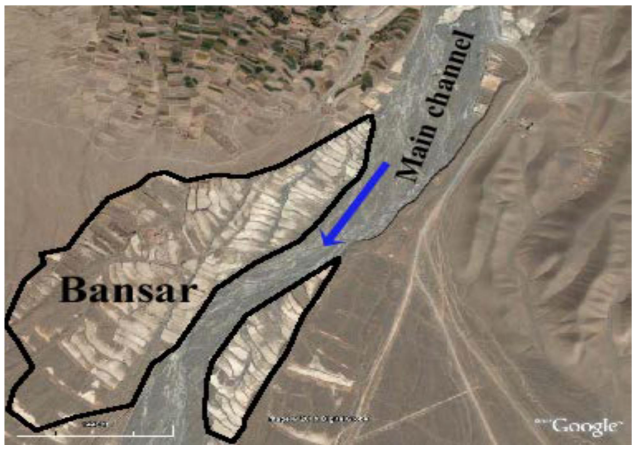

Fig. 1. Satellite image of Bandsar location along a seasonal stream in the study area, Bright tone indicates sedimentation deposited within the Bandsars (Arabkhedri, 2015).

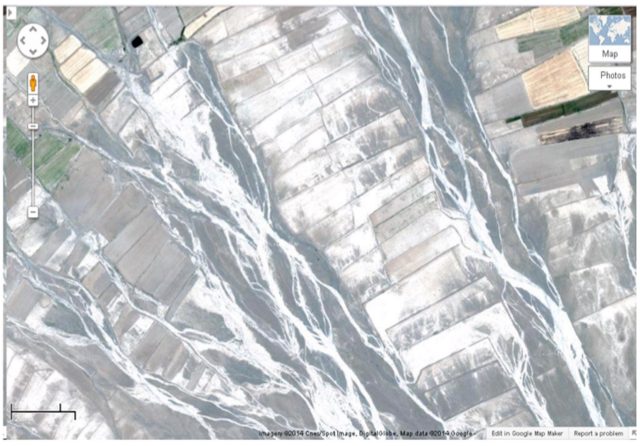

Fig. 2. Closer view of ephemeral streams and adjoining Bandsar fields from Google Earth

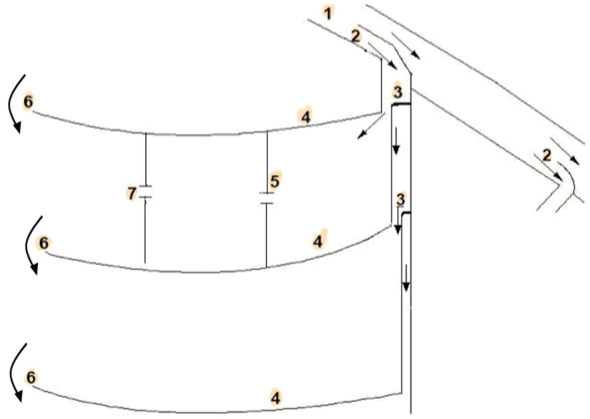

Fig. 3. Bandsar components
1: main stream, 2: inlet, 3: conveying channel, 4: levee, 5: subsidiary weir, 6: end weir of the levee, 7: subsidiary wall (Arabkkhedri, 2015).

Fig. 4. The incoming water spreads behind levees so that the resulting backwater makes the soil moisture to increase to a sufficient level for sustaining compatible cultivation.

Fig. 5. Sediment deposited (light colour) in Bandsar improves both soil texture and fertility.

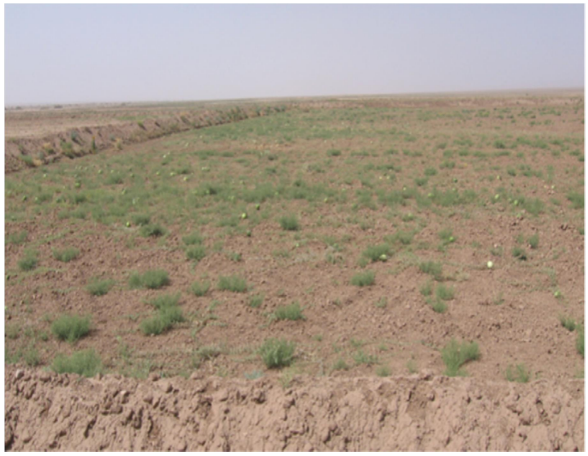

Fig. 6. Selection of crop type depends on the timing and volume of the flooding event.

Some types of Bandsars receive runoff directly from the upstream watershed only when the possible peak discharge volumes will not endanger the Bandsar stability (Nazari Samani et al, 2014). In these instances, the conveying channel and diversion work is no longer needed, as floodwater can flow directly behind the levees to be stored with minimum care and effort.

Water surplus to the Bandsar capacity is directed into the next part (i.e. the next Bandsar) from the end of the original Bandsar. Bandsar numbers and dimensions are selected according to the ground slope and the floodwater harvesting potential. It is usually expected that a certain number of Bandsars can be filled up completely or partially depending on individual flood characteristics. Flooded areas are plowed and cultivated while the sections of Bandsar fields which did not receive runoff water remain untouched and unplanted until other storms provide enough runoff to wet their soils. When the next flood flow occurs, the experienced owners are also able to consider supplementary irrigation for those parts of the fields already irrigated by the harvested flood flow of the previous storm. In general, stream flow hydrology and geomorphology would be very decisive for selecting Bandsar location mainly due to the fact that a minimum of yearly flood water availability should be guaranteed (Figure 4).

2. Materials and methods

Constructing a Bandsar starts with visually benchmarking the levees and channel direction by the landowners, often supervised by more experienced local farmers (Figure 7). The selected levee location is plowed and loosened to generate enough soil to create and compact about a 1 meter high earthen levee. The conveying channel starts from one end of the first levee and is continued upstream and parallel to the main stream channel until they cross each other at the level of the bottom of the stream channel. This would be the floodwater diversion point or conveying channel inlet. When the first flood occurs, the water is diverted from the main stream and flows through the conveying channel to be accumulated behind the Bandsar levees. At this stage, the owners start doing necessary modifications and manipulations with regards to the levees, channel direction, and structures. Locally available plants are often used along the interior toes of the conveying channel preventing any possible erosion. Compared to the areas with sandy soils, Bandsar fields should be larger in clayey soil because of slower water penetration. The slope of the conveying channel is considered so that it will not cause too much sedimentation or erosion along the channel bank. One large channel is divided into smaller ones along the diversion route towards Bandsars located further from the main stream.

Fig. 7. Experienced Bandsar farmers

Irrigation starts at the most upper Bandsar.

The excess runoff is diverted to the downstream Bandsars via levees at the end of the upper Bandsar. Plowing and sowing starts as soon as the water has penetrated into the soil profile and appropriate equipment and machinery can move and work inside. A subsidiary berm or dike divides a Bandsar into smaller fields, guaranteeing that at least the field closest to the inlet will receive enough water for cultivating, even if there is not enough floodwater to irrigate the other fields of the Bandsar. Because of the typical short duration of flood flow, most Bandsar owners are present at the site if they think there will be enough rain to generate runoff flow. A bunch of weeds and grasses have already been collected and deposited at the diversion point to be used for assuring an optimum discharge into the conveying channel.

The selection of the crop type for being cultivated in a Bandsar, depends on the time that the first flood flow occurs. If the runoff happens in autumn, wild annuals (Figure 8) and barley may make the best choice, whereas when the first rain and flooding occurs in winter, caraway and pea would be a better choice, and if flood flows occur in spring, all kinds of melons may be the most beneficial crop types (Figure 9). One should note that the rainy season in Mediterranean regions (like Iran) starts in late autumn (October) and ends in mid spring (April) with no rain during the rest of the year. Sediments carried within the floodwater flow deposit within the Bandsars. These freely deposited sediments often include enough nutrients (animal dung, seed, leaves, and other organic matters) that no additional fertilization may be needed for the fields (Ashouri, 2000). In some cases, Bandsar soil, getting too fertile, becomes unsuitable for some sensitive crops such as wheat, however hardier barley can still be grown.

Fig. 8. During drought periods, Bandsar owners collect, mince, and bind wild annuals grown in Bandsar fields to be used for animal feed during winter.

Fig. 9. Melons irrigated solely with passively harvested runoff in Bandsar field.

Because Bandsars are usually constructed manually, many breakages and holes as well as bank and bottom erosion and sedimentation may happen due to water overtopping the berms or water flowing through animal burrows in the berms. Therefore, Bandsars should be inspected and repaired carefully each year before, and throughout the rainy season. Accumulated sediments and excessively eroded parts should be levelled to ensure the most uniform water distribution within the Bandsar. Animal burrows and wall breaks should be blocked and re-compacted. Making use of fine-grained sediments transported to the Bandsar, owners usually spend some time and effort improving levees stability and increasing Bandsar capacity. Sediment surplus to what is used for Bandsar repair work could be carried away from Bandsar to be used as an impervious material for construction purposes.

3. Results and discussion

There are different types of Bandsars based

on the way floodwater is directed towards the system. A Bandsar can be irrigated directly from upstream catchment or the flow can be regulated (to be less critical) within a supportive levee at the upstream side and then become spilled from end sides into the main Bandsar. In cases of larger catchments, the water has to be distributed into several Bandsars via systems of channel and ditches. Because of the larger catchment area, the latter has a higher chance of being irrigated (even partially) in case of drought conditions. However it requires the presence of the Bandsar owner at the site during flood period for manipulating water among the corresponding channels and ditches. A Bandsar may be fed from a flood stream passing through one or two sides of Bandsar. It can also happen that a Bandsar may be irrigated either directly from the adjacent catchment or by the flood stream passing through the area. Runoff received from the catchment plays a complementary irrigation role for anticipated Bandsar and prevents water loss. In cases where big storms harm the Bandsar (because of overtopping), a confidential Bandsar is constructed at the far end of the downstream part and big enough to reserve the surcharges. Confidential Bandsar can save a lot of water in case of breakage of the main Bandsar, although it remains dry in normal conditions. Water surplus to the conventional irrigation systems (perennial rivers, spring, and Ghanats) may be diverted into Bandsar and vice versa (Extra flood water can be also diverted into the irrigated farms). Road construction can be considered as a very destructive phenomenon when it crosses a Bandsar system. However it gives Bandsar owners the possibility to take advantage of concentrated flow condition which occurs at the bridges and culverts located along the road. Some minor changes are usually required for the Bandsars configuration.

Bandsar has many characteristics among which the following are the most significant ones worth consideration in modern agriculture:

- The basic idea is to reserve moisture as much as possible within the soil to be used by appropriate crops during the growing period
- High quality products can be cultivated in Bandsars because of nutritious soil carried out by floodwater. This means no fertilizer is used in Bandsar and the products are purely organic,
- Construction methods and maintenance works are rapid, simple, and inexpensive so that the risk of failure is not very discouraging,
- Compared to rain-fed agriculture, farming in Bandsar can cause considerably higher grain yield
- A variety of crop type can be cultivated according to the time and volume of the flood occurring during the year.

4. Conclusion and recommendation

By using the Bandsar system, crop yield efficiency can be improved considerably compared to dry farmed agriculture not incorporating passive water-harvesting strategies, because the water-harvesting significantly prolongs soil moisture availability. After the initial investment for Bandsar construction, the cost of operation and maintenance is very negligible such that the farmers' incomes could be very competitive with conventional irrigated agriculture (with its costs of pumping/importing water and fertilizer). This is in spite of the fact that the Bandsar

agriculture might be affected by short- and long -term drought periods. Though, the incomes from the good productive years with good runoff flows usually compensate for the failures that happen during drought periods (Rahi et al., 2007).

Bandsar agriculture is threatened by the following problems:

Climate change resulting in severe irregularities in receiving floodwater flows in terms of magnitude, duration, and frequencies.

Original owners are getting old, and new generations do not like to follow their parents' professions.

Bandsar owners mostly live in villages and are gradually immigrating into larger towns and cities looking for higher living standards and incomes.

Increasing sand and gravel mining operations have caused degradation of stream beds and stream flows so that water diversion may no longer be affordable.

The government should seriously consider supporting Bandsar agriculture by allocating appropriate incentives for the owners as well as establishing supportive legislation to prevent degradation of areas with Bandsar concentration.

5. Acknowledgments

This paper is a summary of the report conducted by the authors under the financial support received by the Iranian Rainwater Catchment System Association (IRCSA).

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