Extreme Risks, Vulnerabilities and Community- Based Adaptation in India (EVA)

A PILOT STUDY

Final Report on WP2.2
Water resources, water use and potential risks in Jalna: impacts of extreme drought on water issues and use

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Abstract

Climate change will increase the vulnerability of societies around the world. Changes in the frequency and magnitude of extreme climate events, such as droughts and floods, require measures to reduce the vulnerability of communities, especially in developing countries. Our region of study in the drylands of Maharashtra, offers an interesting context for studying how ecosystems and rural communities, specifically in the Jalna District, are able to withstand and respond to the extreme drought risks and adapt towards future climate change.

The report is based on outcomes from a two-year Indo-Norwegian research and capacity development project: 'Extreme Risks, Vulnerabilities and Community-Based Adaptation in India (EVA): a pilot study" (2012-2014). Within the research project the impacts of, vulnerabilities and responses to extreme events on agriculture and water resources are assessed in nine villages in the drought-prone drylands of Jalna district, Maharashtra, India.

EVA is about Community-based Adaptation (CBA) to extreme drought risks in nine local villages in the drought-prone Jalna District in the dryland region of Marathwada of Maharashtra related to farming and non-farm livelihood activities. In this report, we describe some of the key identified aspects and challenges related to water resources in the study area. In particular, we focus on how the water resources and the rural agriculture communities were affected by the recent extreme drought (2012-13) in the region; which is considered the worst drought observed in the last 40 years.

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1 Introduction

In this report we present and discuss the outcomes of Work Package 2, task 2.2 on water resources under the project 'Extreme Risks, Vulnerabilities and Community-Based Adaptation in India (EVA): a pilot'. The overall project has assessed the impacts of and responses to extreme events on agriculture and water resources in nine villages in the drought prone drylands of Jalna district, Maharashtra, India.

The aim of this report is to contribute to a better understanding of the water resources dynamics and vulnerabilities in the Jalna District, in particular focusing on water related to agriculture and agricultural management in the communities and how the system was impacted during the major 2012-13 drought.

1.1 Water resources, agriculture and drought in the context of climate change

Water resources are vital to both society and ecosystems, and water-related issues have become the focus of increasing national and international concern and debate. Water is recognised as an increasingly scarce and valuable resource. Reliable supply of clean drinking water is needed to sustain health and water is needed for e.g. agriculture, energy production and manufacturing. Different water uses put pressure on water resources that may be exacerbated by climate change. When addressing issues of water resources availability, accessibility and vulnerability, it must be addressed both from the supply side and the demand side. Climate change is, in many areas, likely to increase water demand while shrinking water supplies. This shifting balance poses a challenge for water managers to simultaneously meet the needs of both (growing) communities and sensitive ecosystems.

Agriculture is the world's largest water user in terms of volume, in general terms it is also a relatively low-value, low-efficiency and highly subsidized water user. In Maharashtra state, even with large urban centers and manufacturing sector, agriculture still constitutes to be a driver of the local economy with nearly 85% of the state's rural working population engaged in agriculture (Census of India 2011)[1]. In the rural communities of the Jalna District, agriculture is the main livelihood activity and the backbone of the communities. Climate change is expected to impact agriculture by increasing water demand, limiting crop productivity and by reducing water availability in areas where irrigation is needed. Changes in the climate, precipitation and water availability could have implications for agricultural production including changes in crop yield, variations in plant tolerance, and prevalence of crop disease, weeds, and insect pests.

Impacts of climate change on water resources are largely experienced through manifestations of modifications in the hydrological cycle (e.g. droughts, floods, storms). The IPCC states with high confidence, that climate change, particularly variation in temperature and rainfall, also impacts the operation of water infrastructure and water management practices (IPCC 2012). Impacts of climate change are estimated to be particularly severe in many developing countries.

In the climate change adaptation literature there is a set of inter-related concepts that underpin the definition of adaptation; risks, exposure, and vulnerability (IPCC 2012, 2014). Vulnerability to climate risks is perceived as a function of the nature of climate risks to which a system is exposed, its sensitivity and its adaptive capacity (IPCC 2012). Climate extreme is, in this context, the

[1] Provisional Census of India – Maharashtra, 2011

occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable (IPCC 2012).

In this report we are mainly concerned with water resources in the context of extreme drought (as a particular climatic event), and we focus on water quantities and water-related agricultural resources, specifically, given that the communities are rural agricultural communities. Changes in the frequency and magnitude of extreme events, such as droughts, require measures to reduce the vulnerability of communities and there is a need to improve understanding of the perspectives and responses of local communities and decision-makers to plan for such events.

The EVA project on an overall level studies the enabling conditions for and barriers to Community-based Adaptation (CBA) to climate change. CBA is already a known concept in the decentralized natural resources literature, and has subsequently been adopted in the climate change literature, including by IPCC in the Fifth Assessment Report (IPCC 2014). As given in Vedeld et al. (2014) one definition of CBA is as: responses to climate change that "provide increased participation by locals and recognition of the local context and the access to adaptation resources to promote adaptive capacity within communities" (IISD 2011, Reid et al. 2010, Baas and Ramasamy 2008).

It important to understand the different water uses and the pressure these put on water resources, both for adaptation purposes and also for sustainable use and management of the resources. Actions and practices of the local communities, e.g. farmers in rural agricultural communities, will influence how the magnitude of impact of an extreme event like drought would be, both for the ecosystem and the communities, and the vulnerability of the water and agricultural resources. There is no uniform universal definition of drought; it is a complex and relative term that depends both on the rainfall and the system/resources/activities under consideration. The IPCC in its Special Report on Extreme Events (2012) defines droughts as "a period of abnormally dry weather long enough to cause a serious hydrological imbalance." The Manual for drought management (Government of India 2009) describes drought as a temporary seasonal aberration, different from seasonal aridity, which is a permanent feature of the climate. In this report we address drought broadly, but focus in particular is on how it is perceived and experienced locally through water and agricultural resources.

Often, several adaptation measures need to be adopted at the local level. There is a need for both scientific and local knowledge as part of understanding the impacts and vulnerabilities at local scale. Drought risk management needs to be tailored to the local context, perspectives, and capacities (Platteau and Abraham 2002, Satterthwaite 2011). In a CBA context, participatory processes involving local stakeholders are emphasised; recognising local context, impacts and vulnerabilities. A critical factor in CBA actions is that community members are empowered to take control of the processes involved (Platteau and Abraham 2002, IPCC 2012, IPCC 2014).

1.2 The EVA-project and study area

The project 'Extreme Risks, Vulnerabilities, and Community-based Adaptation in India (EVA)' is a two-year pilot project (2012-2014) under an Indo-Norwegian collaborative programme funded by the Norwegian Embassy, New Delhi. The EVA project aims to (i) understand the enabling and constraining conditions for CBA to climate change and extreme events; and (ii) develop pilot approaches to research on and capacity-building for CBA.

The EVA project is based on a mixed-method approach, combining analysis of climate risks with participatory assessments of human and natural vulnerability. The project has involved extensive fieldwork at village and district levels, semi-structured interviews, household surveys, policy and institutional analysis, and participatory workshops.

The Jalna district has provided an opportunity to explore the impacts of climate change and extreme weather on water and agricultural resources and the responses at community and district levels. The Jalna district is a central district in the region of Marathwada in the state of Maharashtra in western India (see Figure 1). The average annual rainfall in the Jalna district is about 750 mm. The district quite often experiences drought, whenever rainfall recorded as low as 400-450 mm. During the project we have followed the study area through what is considered one of the worst droughts in the region in 40 years, the drought of 2012-13. Fieldwork has been carried out in three blocks in Jalna District, which was severely affected by the drought.

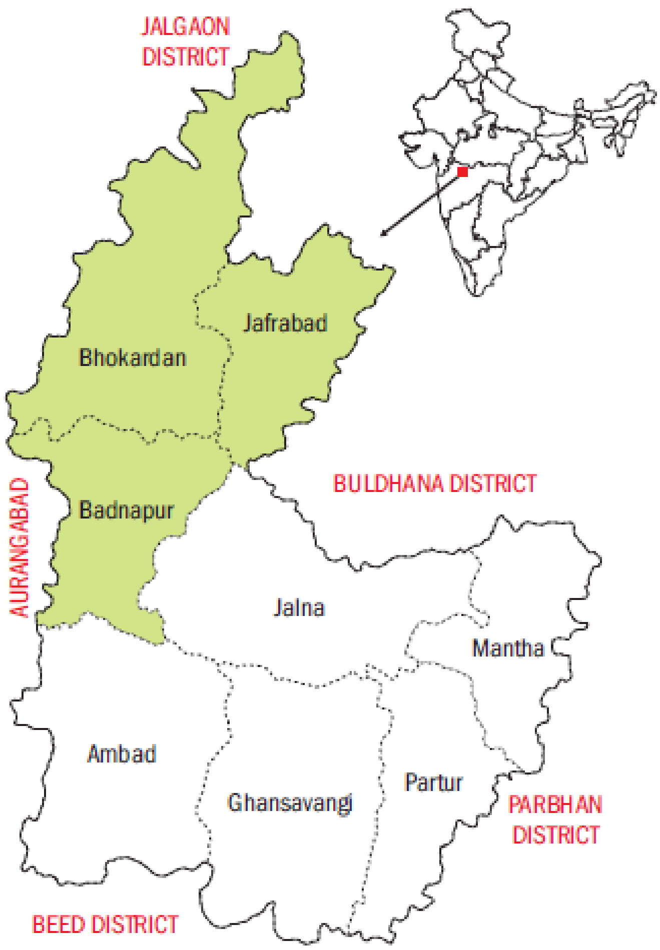


Figure 1. Study area in Jalna District, Maharashtra state, India. The EVA project conducted fieldwork in Bhokardan, Jafrabad and Badnapur.

Three villages were surveyed in each of the three blocks Bhokardan, Jafrabad and Badnapur. The nine villages included in the study are Pimpalgaon Barav, Palaskheda Pimple, Pimpalgaon Thote (EVA Cluster 1), Dongaon, Asarkheda, Niwdunga (EVA Cluster 2) and Kadegaon, Malegaon, Warudi (EVA cluster 3)[2], presented in Figure 2 below.

[2] The clusters are sometimes in the EVA project referred to as the Bhokardan, Jafrabad and Badnapur clusters

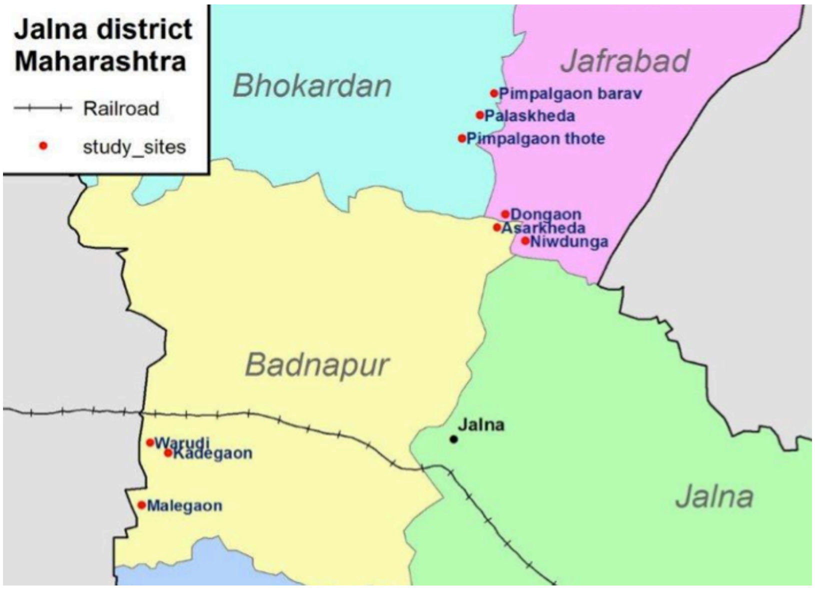


Figure 2. The EVA case villages in Jalna.

The nine villages cases illustrate different kinds of impacts of drought depending on a set of local circumstances (farming system, access to water resources and land, eco-landscape, market access, local leadership, access to external institutions), and local people engagement in different kinds of responses and interactional relationships with external actors.

The rural communities are agriculturally dependent and dominated by cotton cultivation in combination with a mix of maize, pearl millet (*bajra)*, pulses (*tur)*, and soybean in the *kharif* season and sorghum (*jowar*) and to some degree wheat in the *rabi* (winter) season. In the Marathwada region overall cotton and sugarcane are main cash crops. Some farmers have also diversified into cultivating fruits like sweet lime. Most crops are under dryland farming in the area, but a majority of the farmers have and use open dug wells for some irrigation (during the winter season).

Maharashtra has a history of droughts and the state had spells of severe drought during 1970-1974 and 2000-2004. Given the past history of drought in Maharashtra, farmers and rural households in the region resort to a number of coping options. Many of these, nonetheless, tend to be short-term measures, which may even increase vulnerability over time (see EVA WP3.1 report).

1.3 Participatory assessment of vulnerabilities of water resources

Climate change and variability - and changes in such due to climate change - may alter the amount and timing of water resources available to the rural communities. Furthermore, climate change may also alter the demand-side, e.g. with a larger (felt) need for irrigation water due to less rainfall at desirable times. The communities must adapt their water management strategies to both future climate change and the socio-economic context (see EVA WP3.1 report). Hence, in line with the CBA-approach we chose to approach this issue from a local, contextual and participatory angle.

Kiparsky et al. (2006) argues that a lack of political, economic, and social understanding about the interaction between water resources and climate change, particularly at the local level, limits the adaptive capacity in situations of heavy rainfall events and droughts and hinders water projects by international development agencies. Much adaptation research on water resources and climate change focuses on adapting to impacts at regional or national scales/levels rather than understanding adaptation processes at all scales. Though increasingly recognised as important, and a long tradition in India, proportionally relatively few researchers have worked with local rural communities to contextualize climate change and adaptation processes with regards to water resources at the local level.

Determining the impact of climate change on water and agriculture resources typically requires the use of simulation models to predict the distribution and extent of change in key variables that govern crop growth (temperature and evaporative demand) and water availability (rainfall, evaporation, stream flow and groundwater recharge). Modelling in the context of impact and vulnerability assessment, means undertaking a formalized attempt to describe a system; a model is any kind of stringent, internally consistent concept (Schröter et al. 2005). This concept or causal model can in some cases be mathematical and physical models, which allows for computational processing based on time series data. For a vulnerability assessment, the role of numerical modelling is the projection of future states of a system. Modelling of climate change impacts on crops and surface waters is beyond the scope of this report (see EVA WP2.1 report and WP1).

Schröter et al. (2005), importantly, breaks a (potential) modelling path into two broad classes:

1. Activities that take place *prior to* modelling
2. Activities that take place *as part* of the modelling and modelling refinement process

It is possible to build an internally consistent model without engaging the first step, which could answer specific questions about the system but it would not *necessarily respond to stakeholder needs*, as demanded by a vulnerability perspective (Kates et al. 2001; Clark and Dickson 2003; Turner et al. 2003). Hence, in this work we have focused on gaining knowledge and understanding the local context that could be taken further in modelling exercises as deemed relevant and useful (e.g. see Chapter 5).

Luers et al. (2003) advices that adaptation research, instead of determining the vulnerability of a specific place, should shift to assessing the interaction between specific variables of concern, e.g. impacts on/vulnerability of agricultural yield, to specific stressors, e.g. climate change. With this approach the relative vulnerability for a specific variable is identified and its implications for management strategies. We partly follow this strategy by focusing specifically on water resources and vulnerabilities in the context of drought and climate change. However, we do keep the spatial area component in place – the Jalna District with the three EVA study clusters and nine villages- to understand the interaction with the local communities and spatial variances. Within water resources management a spatially bound unit, preferably a watershed or micro-watershed is a relevant management unit.

1.4 Outline of the report

The following Chapter 2 gives information about the methodological approach of the study. Chapter 3 explores water uses and watershed development in the study area. Chapter 4 addresses groundwater and drought as the communities in our study area rely mostly on direct rainwater and shallow groundwater as their main sources of water. In Chapter 5 we look into the issue of integrated drought assessment and managing water resources under climate change, and in Chapter 6 we give conclusions.

2 Approach for addressing water resources in the context of drought and CBA

The EVA-project takes a participatory approach to address adaptation to climatic extremes, with focus on drought. In line with traits of Community-based adaptation (CBA) the project has focused on the activities that start with a contextual and stakeholder-oriented investigation and perspective. This particular report is concerned with water resources under extreme drought as experienced in the case communities in the Jalna District in the Marathwada region of Maharashtra state.

As part of the overall project, Participatory Rural Appraisal (PRA) techniques like focus-group discussions, semi-structured interviews, and field observations were used. PRA-techniques are a family of activities that aim at involving local communities in the problem definition and analyses in a way that to some extent reverses the once dominant role of the outside "expert" researcher and the local "object of analysis". The techniques often involve visual depictions of the target problem and its causal factors in the form of maps, charts, and diagrams (See EVA WP3.1 report for more details).

By applying participatory methods, observations and interviews, we have explored the successes of past and present water management strategies in order to establish potentially effective responses to future climate change. We have combined this work with shallow open dug well measurements and analysis of secondary groundwater data. We also applied participatory mapping for learning about the ecosystem vulnerabilities and risks and local farmers/villagers' perceptions, usage and management of resources (see EVA WP 2.3 report). Specifics of methods that have been used for various components of the study are described in the relevant section (e.g. Bayesian modelling in Chapter 5).

2.1 Method and work process

The analysis of water resources and impacts of drought in the villages is based on data collected by triangulating different types of data collection methods; both qualitative data (key informant interviews, focus group discussions), quantitative data (water levels), field observations and review of relevant literature related to water and agriculture resources drought and climate change (adaptation) in general and specifically in the study region.

Tools that we have applied, on the project level, involves agricultural *seasonal calendars*, *transect walks through the village and the fields* with key informants to learn e.g. about usage of wells and water resources, types and states of crops, water-level in wells, watershed-development structures like bunds, check dams and percolation tanks. We also conducted *participatory workshops and mapping combined with GIS* of the village areas, pointing out major landmarks, land uses, and areas of high, medium, and low drought susceptibility and varied soil quality.

In all the nine villages we aimed for semi-structured interviews with the *sarpanch*, teacher, leaders of watershed committee or NREGA schemes, *gram sevak/sevika*, and other key actors identified through the 'snow-balling method'. Also, semi-structured interviews with key persons responsible for water and agricultural resources were conducted.

Specifically for this study on water resources, a well survey was also designed and conducted to survey 54 wells for one year (December 2012-2013) in the study region. In addition, secondary groundwater data from GSDA was obtained and analysed.

During the project period, the team conducted several visits to the case villages in the Jalna District: April 2012, September 2012, February 2013, July 2013 and October 2013, which allowed us to make observations before, during, and after an extreme drought. We have aimed to understand the main issues related to water resources in the agricultural rural communities focusing both on supply and demand-side aspects. Furthermore, how this was affected by the 2013 drought and providing a basis for important aspects that would need to be addressed or taken into account in deliberation of community-based adaptation (CBA) options.

2.2 Data sources and data availability

The report contains analysis and conclusions drawn from data available through field survey, our analysis of secondary data, GSDA data analysis and its correlation with secondary data, interaction with the local communities and personal visits to the sites:

- field observations
- documents
- interviews
- secondary data
- participatory workshops and tools

3 Water uses, issues and management in Jalna

3.1 Main water uses and issues

Based on our field studies and interaction with the communities we can put forward these main points:

- Water for drinking and agricultural purposes are the main water uses in the case villages, also some for livestock.
- Drinking water is mainly supplied through governmental public open wells in the villages.
- Characteristic for the area is a large system of open private dug wells used for irrigation.
- There is little flowing surface water in the study area as such (but in the larger region there is). There are a few small streams/rivers flowing that are highly season seasonal nature, like the river Laukhi close to Warudi and Kadegaon in the Badnapur cluster. The river was completely dry during the 2012-13 drought. In the case villages, there is a need for water supply from tankers in the dry months. While there is a difference in water availability for irrigation within communities, availability of drinking water is normally assured by the government through tankers. Water tankers are thus, 'a part of the ecosystem' providing water. E.g. all the villages in the Badnapur block, reported that tankers had been coming regularly to the villages during the dry months since the last five years.
- The drought of 2012–13 was noted by informants as a 'drinking water drought', and tanker schemes were intensified. During the drought local farmers were concerned about water availability for drinking, prioritizing use for 1) drinking water for people, 2) drinking water for livestock, 3) agriculture/irrigation.

Tankers providing water to the villages discharge the water in the common public wells or are stationed at pre-designated spots in the villages for people to get water directly from the tanker itself. So, depending in the mode of tanker water discharge, people either draw this water from the public wells, as observed in Warudi, or directly from the tanker spigot into vessels that are lined up near the designated spot where the tankers are parked in the village, like in Malegaon. The photo on the front and back on the report is the Malegaon Village and distribution of water from a tanker. In most of our study cases, the water was discharged into the local wells. The mode of distribution was most likely determined by convenience.

Some farmers also bought water for irrigation; this water is then filled into the private well (the case for some of the wells in the EVA well survey, see Section 4.3). Variability in the frequency of tanker delivery was observed; some villages received one tanker with the capacity of 1000 liters that made two trips in a day, other villages received a total of five trips per day.
Other studies of the 2012-13 drought in the region, document that tankers providing water in the villages for purposes other than drinking, e.g. irrigation, frequent the villages as per the population (10% addition to the 2001 census population) (RedR 2013).

The nine villages under our study reported that they received water either from Somthana Reservoir or the Jayakwadi Reservoir, as response to questions related to the source of the water that was delivered through tankers. The Somthana reservoir is located close to the Badnapur case study villages (about a 30 minute drive from Kadegaon). During the study we visited the Somthana reservoir twice, first in February 2013 and secondly in October 2013 (see pictures below). Irrigation was the original purpose for which a 2.75-km earthen dam had been constructed on the Dudhana River in 1964, creating the reservoir at Somthana. The vast reservoir designed to hold 15 billion liters of water. Water is usually released in January and February for the *rabi* wheat and *jowar* crops, which are irrigated two-three times a month.

During the first visit to the reservoir it was completely dry; this was according to our informant the first time since 20004. When the reservoir is full 20-25 families in the village close to the lake (not among our study cases) together pay Rs 10-15 lakhs a year to the local Gram Panchayat for the right to carry out aquaculture in the lake. In 2012-13 they were instead cultivating melons and legumes in the middle of the dry lake, where the last patches of moist soil remained.

When we returned to the Somthana reservoir in October 2013, the reservoir had filled up well, much due to a fortunate location in the terrain according to a key informant from the water sector. Even though the reservoir was dry in February 2013, tankers were still able to collect water from groundwater wells on the side of the reservoir. We observed a lot of water tankers going up and down the road to the reservoir at that time; we were not able to fully clarify if these were all governmental and/or private tankers.

Figure 3. The Somthana Reservoir. 3a (left): 20th February 2013 it was completely dry due to the 2012-13 drought. 3b (right): 25th October 2013 after the monsoon season it had filled-up again.

We did not manage to visit the Jayakwadi Dam, but a lot was written about this reservoir in the newspapers during the drought. The dam is one of the largest earthen dam and reservoir in Asia with a capacity of 21.2 million cubic meters. Same as for Somthana, also Jayakwadi was reported as empty in April 2013 according to field investigations by RedR (2013). As a result of conflicts during the 2012-13 drought relating to the utilisation of the Jayakwadi reservoir and management of the dam, a permanent water supply for Jalna city was set in operation, as the Jalna city have been dependent on tanker-fed water for many years (Purandare 2013).

3.2 Water management practices, infrastructures and watershed development

Watershed structures in the Jalna District are typically check dams, percolation tanks, and farm ponds, in addition to the many private dug wells for irrigation. Important functions of watershed structures are to recharge groundwater aquifers and/or facilitate water for drinking and irrigation.

In 2008, there were 49 774 open dug wells in Jalna District (Agriculture Contingency Plan for District Jalna, 2011). For water supply and potentially large-scale farms, bore wells may be constructed, but only after a hydrogeological survey (CGWB 2010). It has been suggested that bore wells are mainly to be used for drinking water supply, and not for irrigation (Foster et al. 2007).

Integrated watershed development represents the main approach to dryland farming and drought risk management with emphasis on a ridge to valley approach (Purandare 2013), as followed in the village Asarkheda. 83 % off the arable land is under rain fed farming in the Jalna district, while close to 60 % of the micro-watersheds have not been covered with extensive watershed development (Vedeld et al. 2014). Watershed development activities are being undertaken in Maharashtra state under the State's Accelerated Watershed Development Programme, Marathwada Watershed Development Mission, Artificial Ground Water Recharge Scheme, National Watershed Development Programme for Rainfed Areas and Rashtriya Krishi Vikas Yojana (more on these schemes can be found in the EVA WP3-reports). Farm ponds, village ponds, and water harvesting structures are constructed under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS). According to National Rainfed Area Authority (NRAA 011) the most effective measures in terms of groundwater recharge and cost effectiveness are recharge pits, farm ponds, and earthen and cement nala bunds.

During the drought of 2012-13 reportedly most of the shallow wells in the area went dry; there was already little water in during our field visit in September 2012 after the failing monsoon. In addition to lack of water for irrigation, the farmers showed concern for having enough drinking water for the family and cattle. As previous mentioned, water tankers filled the public open wells used for drinking, and also in some cases the private dug wells were filled with tanker water.

Figure 4. Open wells in Warudi village during September 2012

In terms of spatial variances, farmers in the Badnaphur block, for instance, report that wells close to the seasonal river Lahuki are filling up faster than wells further away from the river bank and at higher altitudes, where wells drain quicker. The river was completely dry during the monsoon of 2012. Farmers related the differences in open shallow well capacities and impacts of drought to the texture and quality of the soil in the various parts of their village (see EVA report 2.3). This is related to the characteristics of the Deccan Traps where shallow aquifers will be influenced by the topography of the area, and weathered material tends to be transported downwards by gravity and water, which leaves thicker layers of weathered materials and soil closer to the rivers and in valley bottoms (see Chapter 4).

Figure 5. Farm pond, Warudi Sep 2012

In addition to the many open irrigation wells in the district, farms ponds were put forward as a particular important asset for the larger farmers (in terms of landholding size), as a facility for storage of water. The stored water is used for irrigation in times of no or low rainfall. Farm ponds can also help recharge groundwater locally in instances where they are constructed without a plastic lining, so that water percolates into the ground.

In the Jalna district, we found that the ponds are mainly built with plastic lining and used for irrigation directly. To prevent evapotranspiration the farmers reported that they put a layer of oil on top of the water. The farm ponds depend on getting the water from rainfall and wells, and they are filled with rainwater directly and/or water from nearby wells or rivers/nalas. During field work in September 2012, incomplete construction of some farm ponds was observed, as farmers had abandoned projects for the time being as "there was no water anyway".

In addition to the farm ponds there are structures like check dams and percolation tanks. Large-scale percolation structures are built upstream in a micro-watershed with the purpose of capturing rainwater that can percolate down and recharge the groundwater aquifers (see photo below).

Figure 6. Watershed structures. 6a (left): a small check dam. 6b (right): percolation tank, Sep. 2012

Percolation tanks are one of the most prevalent structures in India to recharge groundwater reservoirs or local aquifers both in alluvial and hard rock formations. The efficacy and feasibility of the tanks are better where rocks are highly fractured and weathered. The Jalna District is located in the so-called Deccan Traps, and here water can travel along the fractures in the hard rock, thus there may be areas where the water can travel faster to fill the aquifers (see Chapter 4). During extremely dry weather, it is possible that water may not reach the aquifers due to limited availability water for percolation to lower levels.

A well-known principle in Watershed Management is the Ridge to Valley approach; it includes treatment of all categories of land and water resources in the area based on its capability classification. In our nine villages, two villages, namely Asarkheda in the Jafrabad cluster and Pimpalgaon Thote in the Bokhardan cluster have implemented such programs with the help of National Bank for Agriculture and Rural Development and local Civil Society Organisations viz. Marathwada Sheti Sahayya Mandal, Krishi Vigyan Kendra and Dilasa. In the Badanapur cluster, the village Malegaon has not gone for a 'single-type' watershed project with ridge to valley approach, but have implemented different types of activities related to land development and drainage line treatment. This was done through different schemes. Consequently, in Malegaon the density of watershed works is high. The topography of the area in this village is not undulating and hence the treatment of watersheds in this area do not need ridge to valley approach as a priority. Watershed saturation even up to 50 % is a long-term process and requires continuous interventions. The ridge to valley approach implemented in a stipulated time frame, as a rule of thumb, cannot saturate the watersheds even more than 30 %. Hence, we understand that the three villages Asarkheda, Pimpalgaon Thote and Malegaon have a better presence of watershed activities compare to other villages in the clusters.

We found, through interviews and observations, that a critical constraint in the functioning of the watershed development structures in the case study villages in Jalna is siltation and lack of proper maintenance. This is a prevalent problem in watershed development all over India (Purandare 2013). Check dams are always subjected to siltation, thus reflecting an "unavoidable" technical issue. However, it is also a demonstration of a weak participatory process at the community level and limited capacity and sustainability of the local Watershed Development Committees across the villages to take on maintenance work (Vedeld et al. 2014). Hence, this contributes to the vulnerability of the system since the structures that are set up fall into disuse much before the anticipated life-expectancy according to plan during the actual implementation. To combat some of these issues, as a response to the 2012-13 drought, the Government of Maharashtra launched a major programme to renovate several watershed structures, dams and rivers (Vedeld et al. 2014).

3.3 Irrigation practices and water-requirements of crops

The nine rural case villages are agricultural communities dominated by cotton cultivation in combination with a mix of maize, pearl millet (*bajra)*, pulses (*tur)*, and soybean in the *kharif* (monsoon) season and sorghum (*jowar*) and to some degree wheat in the *rabi* (winter) season. Some farmers have also diversified into cultivating fruits like sweet lime.

About 75 % of the arable land is under *kharif* crops, and about 40 % are under *rabi* crops. Area under double crops is just 15 %, while area under irrigation is 7.8 % which is far below the state average. Cotton is the main cash crop grown and is at district level grown on more than 50 % of the arable *kharif*-land, whereas jowar is grown on more than 70 % of the arable *rabi*-land[3].

Cotton is grown by the majority of farmers, often intercropped with *tur*. Maize and *jowar* are food crops which are also grown for fodder, and can be used as fodder in case of failed crops. Most crops are rainfed in the area, but a majority of the farmers have and use open dug wells for some irrigation (during the winter season), see the table below.

There are differences with regards to how water-intensive the various crops are, which influence demand, usage and vulnerability of water resources. Sorghum (*jowar*/ *jwari*), pearl millet (*bajra*/ *bajri*), and finger millet (*nachni* /*ragi*) have always been part of Maharashtra's traditional agriculture and are less water-intensive. The main cash crop cotton is considered a water-intensive crop, yet economically important for the communities. In the Marathwada region, as such, also sugarcane is a main cash crop, which is also water-intensive. The exact water use for cotton production differs considerably between countries, particularly due to differences in climatic conditions (evapotranspiration, effective rainfall) (Chapagain 2005).

India, on an overall level, according to Chapagain (2005) take a particular position by producing cotton under high evaporative water demand (800-1000 mm), short-falling effective rainfall (400 mm), and partial irrigation only (between a 1/4 and 1/3 of the harvesting area), hence resulting in relatively low overall yields in global comparison. Yet, even though India achieves low cotton yields per hectare, the blue water requirements (i.e. irrigation water) per ton of product are much lower in India compared to Pakistan. So, the exact water usage of cotton will vary with climatic conditions, but as can be seen from Table 1 below cotton is among the top crops when it comes to water consumption/needs.

[3] Jalna district information page http://jalna.nic.in/html/distp.html and DSAO (Jalna, 2012)

Table 1. Water-intensive crops

Crop	Typical water requirement (in litres) per kilogram of crop
Cotton	7000 – 29 000
Rice*	3000 - 5000
Sugar cane	1500 - 3000
Soya	2000
Wheat	900

Source: WWF (2003). * Rice was not grown in the study area but is included for comparison

The values in the table are not specific for the Jalna District, but it still gives a general picture of the importance of crop assessments in the context of water resources management and climate change adaptation measures.

Millet crops are important in adaptation to climate change, as they need less water and have carbon-fixing properties, and also can withstand drought pretty well. But their economic value currently does not provide incentives for farmers to grow these crops. The farmers adjust their agriculture activates according to the rainfall pattern. However, a crop decision is not only made on basis of rainfall, it is also based on marked-based (economic) considerations. Diversification of crops to include horticultural crops has potential to increase farm earnings, but requires supporting infrastructure for risk reduction and value addition (e.g. cold storage and agri-processing enterprises. Furthermore, it may potentially be more water consumptive and require improved irrigation infrastructure. More on crop practices and impacts are described in the EVA WP2.1 report.

Key adaptation options relating to water resources in the agricultural rural villages involve promotion of protective irrigation and use of efficient irrigation technologies, such as drip and sprinkler. When it comes to irrigation, Table 2 below gives an overview for the EVA case villages. Even with a relatively low percentage under permanent irrigation, irrigation is one of the main water uses in the area. About 1/3 of all farmers in the case villages have invested in drip irrigation and/or sprinkler irrigation**.** In the EVA work on adaptation options (WP4) farmers noted drip as important, but some also remarked that water needs to be available in the first place. Some farmers also rated it to very important in terms of conserving water (see de Bruin et al. 2014, WP4 report, p. 44). Some households mention costs as a constraint for adopting drip (de Bruin et al. 2014, p. 51).

According to the table, none of the case villages in the Bhokardan block has land under permanent irrigation. These are less developed villages than for example the villages in Badnapur. Of the villages in the EVA2 cluster, the village Asarkhdeda has the highest area under seasonal irrigation. This is one of the more developed villages in terms of watershed-development activities.

Table 2. Irrigation status of EVA villages

Village	Block	Popula-tion	House holds	Land under rainfed agricul-ture (%)	Land under seasonal irrigation (%)	Land under permanent irrigation (%)	Area under cultivation (acres)	Summer crop / Perennial
Thote Pimpalgaon	Bhokardan	n.d.	190	77	23	0.0	930	
Barav Pimpalgaon	Bhokardan	1120	245	79	21	0.0	1030	
Palaskheda Pimple	Bhokardan	1180	234	79	21	0.0	910	
Dongaon	Jafrabad	1510	263	79	20	0.2	1029	Vegetables
Niwdunga	Jafrabad	1320	281	74	26	0.7	1022	Vegetables
Asarkheda	Badnapur	1520	212	54	45	1.0	1153	Vegetables
Kadegaon	Badnapur	3500	125	69	29	2.0	2450	Sweet orange
Malegaon	Badnapur	1100	100	54	44	2.2	1140	Sweet orange
Warudi	Badnapur	1384	100	61	25	13.7	1970	Sweet orange Pome-granate

Source: AFPRO 2012 fact sheets about the EVA villages.

3.4 *Water policies*

In an adaptation context, institutional arrangements - and interplay with these on various levels - will influence both potential impacts on water resources and the potential for adaptation to climate change on both local and multi-level scale. Policies in place and how these influences current resource management and vulnerability/risk are addressed within EVA WP3.2 report on institutional aspects. Water is a state issue; here we list the recent main laws and policies on state level which may also apply for Jalna District in specific contexts.

- In 2003 the State of Maharashtra formulated the State Water Policy. Main features of this policy are an integrated and multi-sectoral approach in planning, development and management of water resources.
- The State has also in the last decade passed two major legislations:
    - The Maharashtra Water Resources Regulatory Authority Act (2005) which enabled establishment of Maharashtra Water Resources Regulatory Authority in September 2005 with the aim of contributing to efficiency in water resources planning in an integrated manner.
    - Maharashtra Management of Irrigation Systems by Farmers Act (2005), enabling formation of legally empowered WUAs in irrigation scheme and transfer of irrigation system management responsibilities to legally empowered Water Users Associations (WUAs).

- When it comes to groundwater efforts have been made to change the law governing groundwater in India already from the 1970s. Maharashtra state has been one of the front-runners in this respect, e.g. with the Maharashtra Groundwater (Regulation for

Drinking Water Purpose) Act 1993 explicitly taking into account groundwater. Yet, the evolution of law on groundwater is still in a flux and an area in need of further development. The Maharashtra Groundwater (Development and Management) Bill (2009) calls for the setting up of a State Groundwater Authority and District-Level Authorities to manage and regulate groundwater usage in over-exploited areas, in partnership with local communities. It aims to facilitate and ensure sustainable and adequate supply of groundwater of prescribed quality, for various categories of users, through supply and demand management measures, protecting public drinking water sources. The bill also envisages registration of well owners, rainwater harvesting for groundwater recharge, registration of drilling rigs, declaration of water scarcity area, and prohibition of construction of well in certain areas. Overall, the bill extends the control that the state has over the use of groundwater, yet some say that it lacks a proper thinking through all the checks and balances that needed to be introduced alongside and that it is not fully adapted to the current challenges that need to be addressed (Cullet, 2010). The bill has been approved by the President and is awaiting a formal directive from the Maharashtra Governor for implementation[4].

In order to assess the availability of groundwater and to ensure maximum accuracy in groundwater estimates, the Central Government has, from time to time, appointed committees comprising groundwater experts and has laid down guidelines for this purpose. More on this can be found in GSDA et al (2014).

There is a concern of overexploitation of groundwater, but has not been reported for our nine village as of now.

[4] Maharashtra groundwater bill gets presidential nod, January 28th, 2014. Down to Earth. http://www.downtoearth.org.in/content/maharashtra-groundwater-bill-gets-presidential-nod

4 Groundwater resources and drought

Groundwater resources play a major role in India as a whole and are crucial for meeting water demand of both rural and urban areas (Kumar 2007). The ability to manage future water needs would depend on a proper understanding of the availability of groundwater and the nature and magnitude of groundwater issues. Groundwater has been the primary source of water supply for domestic, agricultural and industrial uses in Maharashtra.

In many of the villages in the district, groundwater is the main source of water, and groundwater has special significance for agricultural development and irrigation in the district. The present stage of groundwater development in Jalna District is reported at about 43 % (CGWB 2010), which is at the lower end in comparison to other regions. There are, however, also variations in different stages of groundwater development within the district; it varies from 27 % in Ghansawangi to 59 % in Badnapur (CGWB 2010).

In 2010, the Central Ground Water Board (CGWB) reported that major parts of Jalna District were showing falling groundwater level trends in northern, southern, and eastern parts of the district, comprising almost entire areas of Bhokardhan, Jafrabad, Ambad, and Partur, and major parts of Jalna block in central part of the district (CGWB 2010). Thus, they urged that future water conservation and artificial recharge structures should be prioritized in these areas. However, none of the blocks in the Jalna District are as of now reported as over-exploited in terms of groundwater resources (Agriculture Contingency Plan for District Jalna 2011).

Groundwater dynamics and assessments are complicated. There has been some critique of ways of analysing for over-exploitation. As a result of the recognition of the need to integrate economic and social considerations in assessing degree of exploitation, this was reflected in a revised methodology proposed by Ground Water Estimation Committee of 1997 (NABARD 2006). But, how far such concerns are integrated in actual assessment is, yet, open to question. We did not address this further in our study.

One of the dominant perceptions of the farmers about the consequences of falling water levels, drying up of wells etc. - is that this happens due to frequent failure of monsoons and declines in rainfalls, sharply affecting natural recharge rates. Rainfall rates and changes in such is of course instrumental, but we also see from secondary data that e.g. the rainfall level for the 2012 drought in several places not were lower than it was in the previous large drought, the 1972 drought. Farmers seem to a less degree to perceive well proliferation and increased groundwater draft as major factors also leading to potential over-exploitation and vulnerability of the water resources.

4.1 Influence of geology and geohydrology on groundwater in the area

Geohydrology is critical for managing scarce water resources in a drought situation. It will vary under what geological conditions drops in water levels occur to which degree. Several semi-arid and arid areas in India fall under hard rock conditions, as almost the entire Maharashtra. Jalna District is underlain by basaltic lava flows and alluvium, which has specific characteristics when it comes to groundwater dynamics.

The basaltic lava flows is part of the Deccan Traps, which occupy about 98 % of the districts area. In the Deccan Traps, occurrence of groundwater is controlled by the highly variable water-bearing properties of the different flow units, which usually have poor to moderate permeability depending on the presence of primary and secondary fractures and porosity. The formation is thick and comprises scores of lava flows of 5–25 meters of individual thickness. Each flow comprises a lower zone of hard and massive basalt, which has primary (inherent) porosity and permeability close to none, and an upper zone of vesicular basalt, i.e., basalt-containing cavities, also with limited primary porosity (CGWB 2010).

Typically, hard rock areas such as the basaltic rocks are considered limited in their groundwater potentials and heterogeneous in occurrence, which poses some challenges both for groundwater utilization and management in the region. Yet, there are also nuances in this picture. Weathering, joints and fractures 'impose' secondary (induced) porosity and permeability to the formation and these zones form potential aquifers. Hence, hard rock aquifers are confined mostly to the weathered residuum, fracture and fissure section generally up to the depth of about 60 meter. Furthermore, it is mainly in the lower ground that a deep weathering profile of the Deccan Traps Basalt is preserved, that can form a continuous perennial (lasting) groundwater body of significant storage. In the recharge zone infiltration capacity is fairly good, but storage is generally low. Hence, wells tend to dry out in the dry season and under drought conditions (see Figure 7).

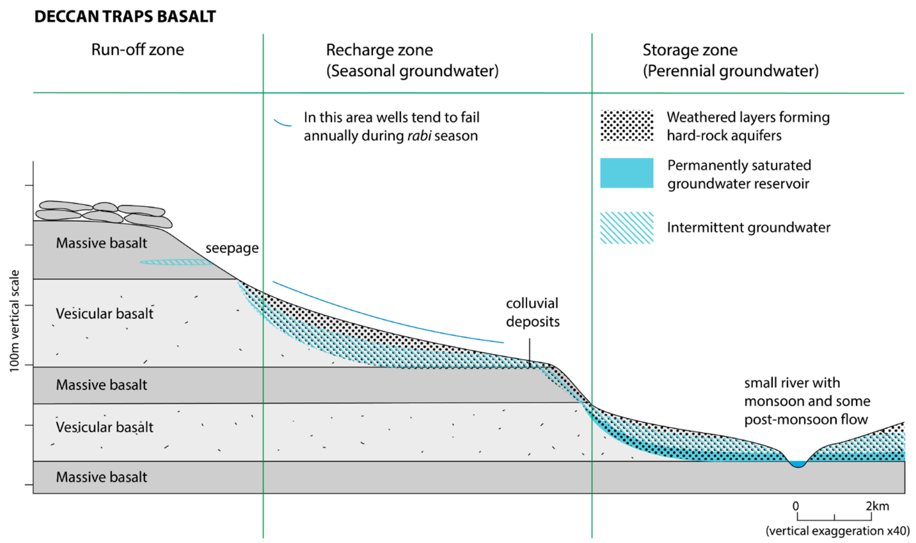


Figure 7. Typical hydrogeological cross-section of a Deccan Trap Basalt micro-watershed (modified from Forster et al. 2007)

Typical for the Jalna District are shallow aquifers that show erratic variations in the ability to store and transmit groundwater within small distances. Hence, as a consequence, local variations in well water yield across small distances can be seen, which lead to localized impacts and variations of drought events on the groundwater resources. Areas of Jalna District where weathered jointed and fractured zones in the Deccan Traps are 20–40 meter thick, aquifers have considerable groundwater potential and wells located in such areas can yield about 100–250 m3/day according to CGWB (2010).

For small-scale farmers, the most dominant and feasible mode of shallow groundwater extraction is through dug wells of 10–15 meter depth and 5–8 meter diameter. For areas with low altitudes specifically, 15–25 meter thick weathered, fractured, and vesicular zones are chosen (CGWB 2010). The deeper aquifers are tapped by bore wells typically 60-100 meters, up to 200 m below ground level and under favourable conditions bore wells can yield 2–18 liters per second or 7.2–70 m3/hour (CGWB 2010). Yet, there are several challenges with use of bore wells in this area: difficulties in exploration and assessment of the resource, risk of not encountering an adequate groundwater supply (Limaye 2011), and potential risk of rapid depletion (Foster et al. 2007).

Hence, deep bore wells may potentially yield limited relief in the region in the context of future droughts.

In hard rock aquifers, such as the Deccan Traps, groundwater rarely occurs across the topographical water divides, and the water table tends to follow the topography, and each basin or sub-basin can be treated as a separate hydrogeological unit for planning (Limaye 2011). Two of the villages, namely Asarkheda and Thote Pimpalgaon implemented an integrated watershed development programme following the 'ridge to valley' principle for area and drainage line treatments (see previous chapter).

4.2 Groundwater (GSDA) data analysis

Jalna District and the Marathwada region received significantly less rainfall than normal in 2012 (see EVA WP1 report). Total 114 Talukas (blocks) in the Marathwada region received less than 75 % of the normal average rainfall for June-Oct 2012. Jalna was the only district in the region receiving less than 50 % of the normal average. As a result, reservoirs did not get the expected volume of water, and consequently also groundwater recharge became a problem.

From analysis of observation well data from the Groundwater Surveys and Development Agency (GSDA) in Jalna, we can observe that the distance down to the water level in the observation wells of the three blocks Bhokardan, Jafrabad and Badnapur in which the EVA villages are located increased between October 2012, compared to the five-year average (2007–2011) for October (see figure below). In other words the water level was significantly lower than normal for all the three blocks in the post-monsoon season. The increase in distance, the difference between the light grey and grey columns, varies between 3.7 and 4 meters. After this rainfall the area did not receive much rainfall before next monsoon season.

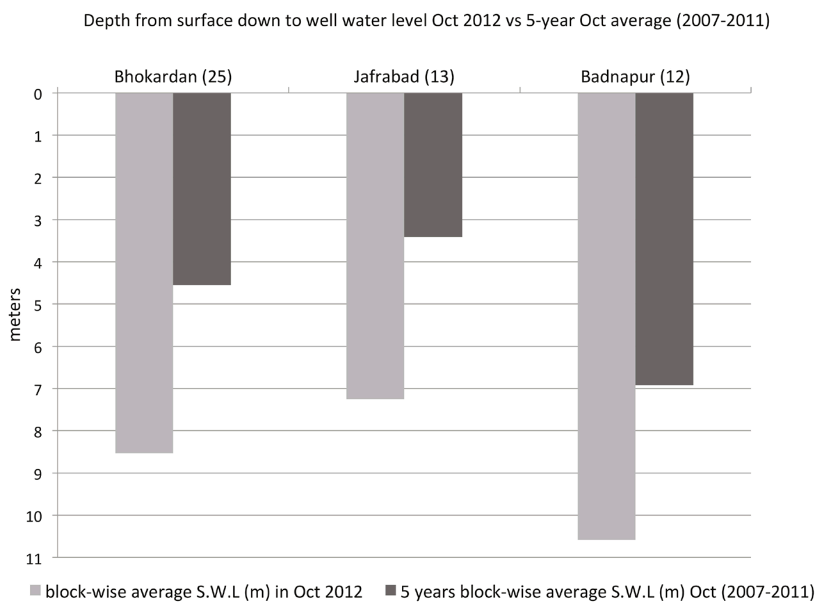


Figure 8. Depth from surface down to well water level in October 2012 versus the five-year October average (2007–2011) (Numbers in brackets are observation wells included in each block)

See more on groundwater in the state in the most recent report by the GSDA et al (2014)[5]

[5] https://gsda.maharashtra.gov.in/GWSpdf/Talukawise_GWA2011-12.pdf

4.3 *EVA Well survey*

Within the project a well survey was conducted between December 2012 and December 2013. In total 54 wells were surveyed each month, with nine wells from each of the three EVA study clusters with three wells in each of the villages (Figure 9).

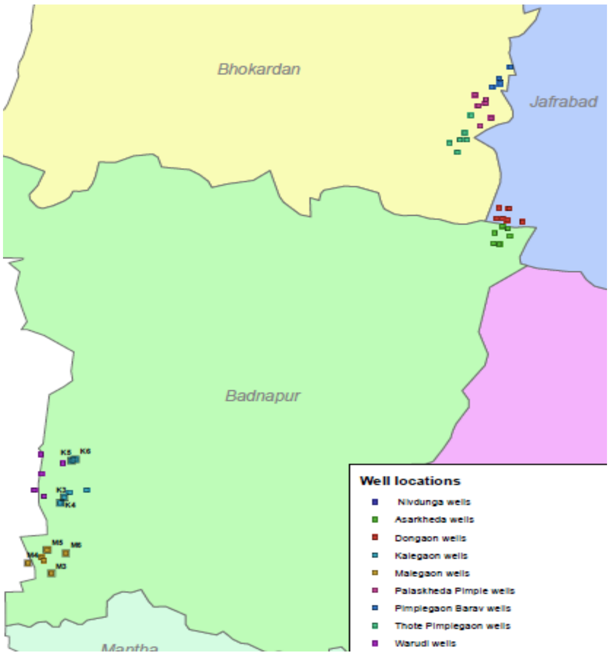


Figure 9. Map of EVA survey wells

The purpose of the survey was to gain insight into spatial dynamics and variation in the area and to learn more about the farmers' management of the resource. In the context of Community-based adaptation (CBA), a goal was also to look into participatory monitoring of wells as a relevant activity to engage the communities in (EVA WP5 work on capacity building).

At the onset of the survey general data about the wells were measured and collected, including location, depth, diameter, ownership etc. In the duration of the survey measurements of the water level in the wells were conducted by AFPRO and/or trained locals from the villages once a month, in most cases after the 15th of each month.

Location data was gathered by use of GPS, well dimensions and characteristics by measuring tape and interviews with the farmers owning the wells. Water levels were measured with measuring tape from an agreed fixed reference point at the top of the well. To ensure that the same reference points were used for all measurement, a mark was made. In addition, photos were taken, and information about well usage was collected. See Annex for more on the well survey. A one year survey is too short to make solid conclusions, and for the 2012 drought we do not have measurements from the onset of the drought. Yet, the survey has contributed to gaining a better understand the conditions in the study area better and also revealed interesting results that corroborate the findings from the field observations and interviews.

In terms of the survey wells, the average elevation for their location is 569 m.a.s.l (median 574 m.a.s.l), the average total well depth is 14 meters (median 12 meters) and the average (and median) diameter is 6 meters. The median approximate year of construction is 1985.

Flooding is most common way of irrigation, but also drip (and some sprinkler) is used by some of the farmers. Cotton and Jowar are the main crops grown. Some of the well owners do get water into their wells from water tankers (trucks), in which case the water is purchased by the farmers themselves. They pay Rs. 700 for one tanker and the capacity of each tanker is 5000 litres. The farmers who buy tanker water require more water not due to the drought impacts, but due to scale and nature of crops that they grow (larger farmland /cultivated area; more water consumptive crops etc.)[6].

Figure 10 below shows the elevation of the EVA wells as how they are located in the landscape. The three clusters are the study clusters of the project, with three villages in each cluster: EVA Cluster 1 (Palaskheda Pimple, Thote Pimpalgaon, and Barav Pimpalgaon, all in the Bhokardan block), EVA Cluster 2 (Asarkheda, Niwdunga, Dongaon, in the Badnapur and Jafrabad block) and EVA Cluster 3 (Kadegaon, Malegaon, Warudi, all in the Badnapur block) The ID of the wells reflects the village in which they are located.

Figure 10 shows that the wells in 'EVA cluster 3', the Badnaphur block (Malegaon, Warudi, Kadegaon), is in a lower-laying, flatter area than for the two other clusters.

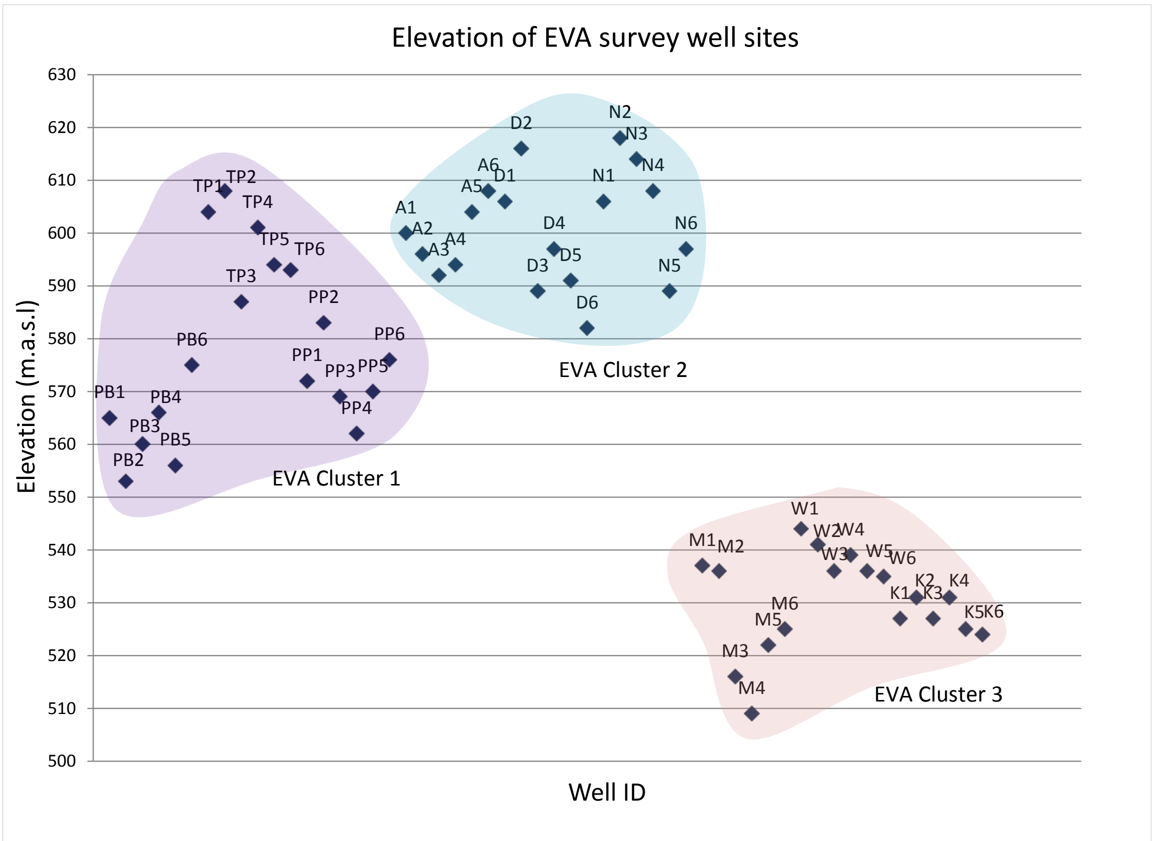


Figure 10. The elevation (meters above sea level) of the EVA wells, as they are located in the landscape.

From Figure 11 below we see that Cluster 3 has the deepest wells (in our survey), and also with the most variance.

[6] Information from AFPRO based on interview with farmers during well survey.

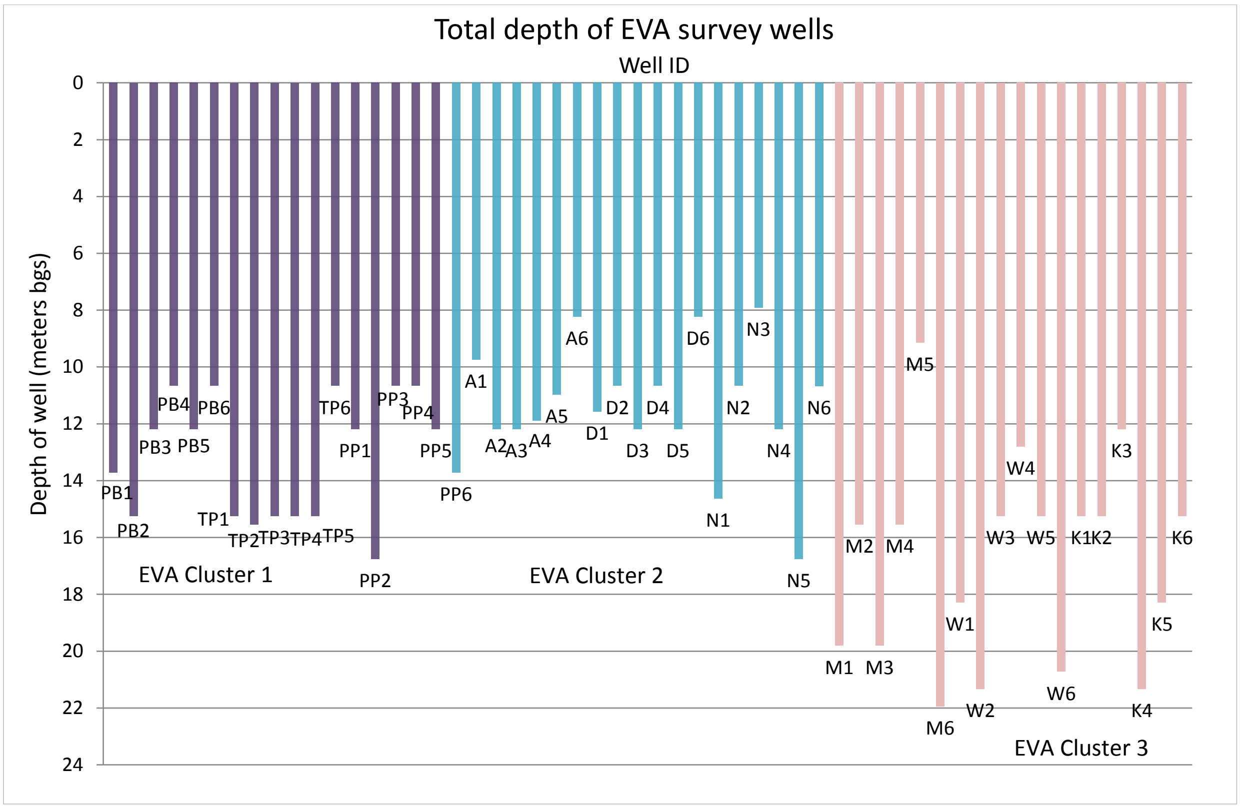


Figure 11. Total depth of the EVA survey wells (meters)

A plot of monthly water level measurements for one village for each of the cluster (Dec 2012 - Dec 2013) shows some of the well dynamics (see Figure 12 below). The picture is not surprising for the area, as when the rainy season starts, the well fills. It does confirm the dependency of these communities on the rainfall. In addition to the hydrogeology itself, the shallow wells are very much governed by the rainfall pattern.

When it comes to how the December of 2012 (the first month of the EVA survey) compares to December 2013, the plots in Figure 13 below demonstrate the significant difference in water levels. Most wells had gone dry, and been dry for a while in December 2012 after the failing monsoon of June-Sep 2012. We see also that after a good rainfall during the following year's monsoon (as was the case in 2013) the wells filled up again.

If we look at the water levels below ground surface, the water level is as high as surface level (0 m below ground surface (bgs)) towards the end of the monsoon for several wells. The average water level in all the 54 EVA wells was 13 meter bgs in December 2012[7]. In comparison, in December 2013 the average water level was 3 meters bgs.

Some of the farmers told us that several of the shallow wells in this region do "normally" run dry at the end of the season due to their characteristics. Since we do not have a longer time series, only limited comparison with the data can be made. But again, the picture confirms the sensitivity towards changes (and variability) in rainfall, and hence also vulnerability to and impacts of drought.

[7] Or lower since several wells were dry, total well depth used for the dry wells for calculation of average.

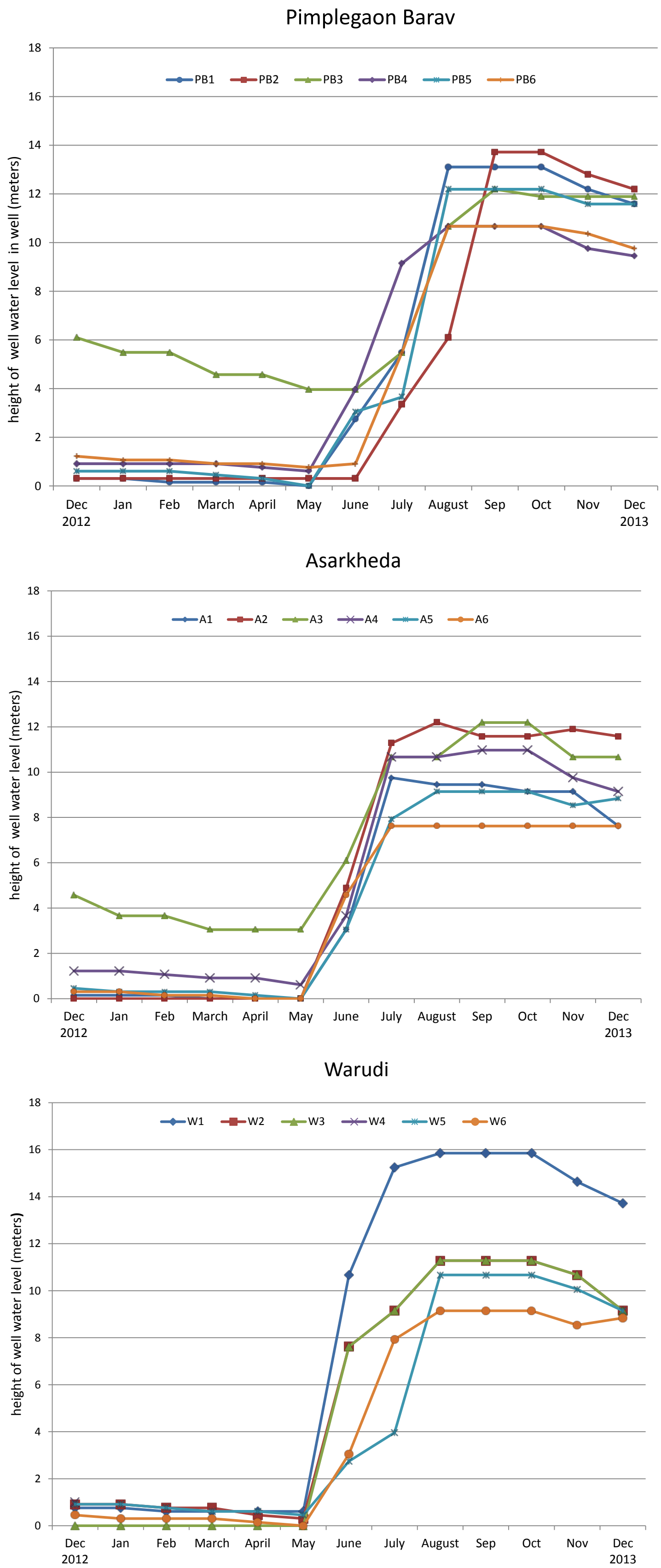
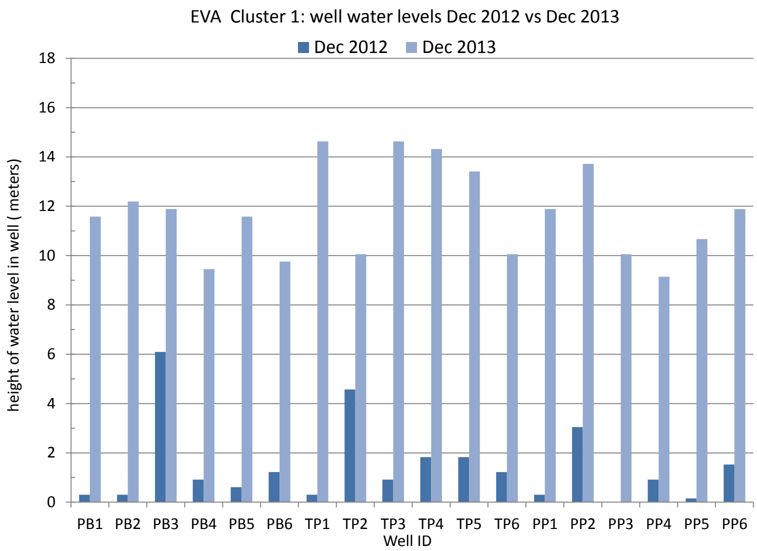
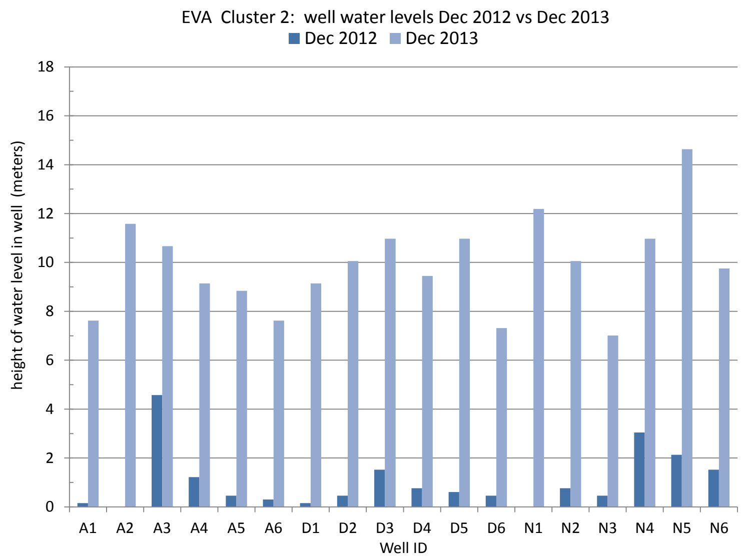


Figure 12. Well water levels (height of water column) (meters) in three wells.





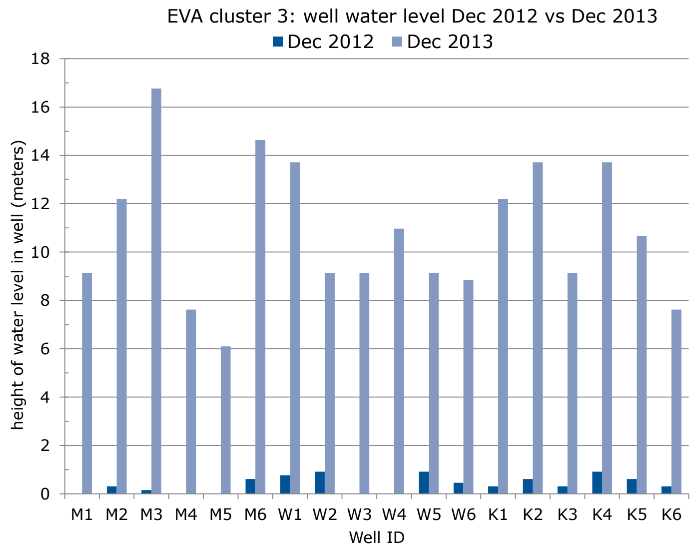


Figure 13. Well water levels (height of water column) (meters) in the three study clusters.

More details on the EVA Well survey, and the data, can be found in Annex 1.

4.4 *Groundwater and climate change*

The actions and practices of the local communities (in particular the farmers in agricultural communities) will influence how the direct impact of an extreme event like drought would be to the local community.

The IPCC 5 report has categorized the limits and barriers to adaptation into physical and ecological limits, technological limits, financial barriers, informational and cognitive barriers and social and cultural barriers (Adger et al. 2007). Limitations arising from the natural environment evapotranspiration linked to increased temperatures, can affect groundwater recharge rates and the depth of groundwater.

Deeper aquifers respond to droughts and climate fluctuations more slowly than surface storages. Hence, aquifers *can* act as a resilient buffer during dry spells and drought, especially if they have a large storage capacity. However, as noted for the Jalna District, the hydrogeological structures are somewhat complicated at the Deccan Traps, and hard basalt rock makes it difficult to filter or store water. We also see that the shallow wells and groundwater aquifers respond quite quickly and seasonally to changes in rainfall. Hence these resources might have limited capacity to function as a buffer in terms of climatic extremes like prolonged extensive drought events in the area.

5 Integrated drought assessment

In most cases, the drivers of droughts are context-specific, often inter-linked and act over different time scales. Moreover, how a drought is experienced and how it will impact locally is contextual. There are also different types of drought: meteorological, agricultural, hydrological, socio-economic with different 'ties' to the water resources (see e.g. EVA WP 2.3 report for more on the different drought types). As a part of the study we wanted to get a better picture on how this was processed at the local level.

As a part of this work we conducted two 'pilot studies' within the overall study. Firstly, we conducted a participatory mapping exercise combined with an NDVI analysis to assess local impacts of and vulnerabilities to drought. Secondly, we carried out a first initial study of (setting up a) Bayesian Network model over the various types of droughts, to make reflections on how various elements are connected in the ecosystem.

5.1 Participatory drought mapping and NDVI index study

In the project we conducted a participatory mapping of water resources and drought-risk zones in the villages. Properties of the ecosystem, such as soil cover, soil quality, geo-hydrological- and variances in such- all influence how the water and agricultural resources area affected. During participatory drought mapping we addressed how the impacts and vulnerabilities were experienced /perceived on a very local scale by the communities.

During the exercise, which functioned as a dialogue tool to explore and discuss the local conditions between the project team and the villagers and among the local themselves, aspects were discovered which resonate with the secondary data. Intra-village variations between zones of good, medium, and low-quality agricultural land became clear to the team during the participatory mapping (Figure 14). See EVA 2.3 report on details on the mapping process and the maps (Barkved et al. 2014).

Figure 14. Participatory mapping of drought impacts and vulnerability.

The mapping helped to gain understanding in how the locals farmers considered drought through water and agricultural resources. It was apparent that to the participants from the communities (mainly farmers) drought was about impacts (agricultural and hydrological drought), not just reduced rainfall (meteorological drought) in itself. The mapping revealed micro-scale spatial variations in wells and agricultural sensitivity due to soil quality, soil depth, and access to irrigation. Farmers reported on the importance of good quality, deep, black cotton soil near village drainage lines which also was connected with good agricultural yields. During the discussions in the mapping exercise, it became apparent that many watershed structures such as check-dams and percolation tanks have very localized effects in the villages. The geo-hydrological conditions of Jalna formed by basaltic rock with dispersed and shallow aquifers do not permit substantial recharge of a common groundwater aquifer underlying the whole village land.

Furthermore, the mapping process also revealed that it is not just the natural conditions that govern where crops are cultivated and related irrigation wells established. E.g. in the Warudi village, in the Badnapur block, the areas close to the main road between Aurangabad and Jalna City were reported as attractive (and expensive) agricultural land due to the easier marked access. The same areas were reported to also have low(er) soil quality and wells that were running dry easier than other areas of the village, e.g. yet due to the location still attractive for crop cultivation. Hence, this was reported as an area where both many wells are located and where they are strongly affected by drought. In terms of how the 2012 drought had affected the villages, e.g. participating farmers from Warudi told us that they in normal years were able to produce a second crop - a *rabi* crop - on the soil moisture left from the monsoon rain, but this was not possible in 2012-13.

We found that the mapping process functioned as a useful (process) tool for quickly gaining an understanding of broader field issues and how the local farmers live with their land and water resources. However, there are several aspects to bear in mind for further use; it is time-consuming and it can be a challenge to secure both inclusion and voice of all relevant participants of the village population. While researchers and project planners may actively ask for all stakeholders' viewpoints and interests during discussions, the views of the most marginalized (and possibly climate-vulnerable) may not necessarily be voiced in all types of forums. We also noted that women tended to rarely speak during plenary sessions, and they often left quite early into the group exercises. For some activities, the project team did organize separate group sessions for women, but not for the mapping. Finding good ways to work with mixed groups would be preferable, as both women and men equally live with the water and land resources as part of their collective community.

5.2 Bayesian Networks for drought risk assessment

Of key interest is gaining increased insight into the dynamics of adapting to drought (extreme events) through mapping and assessment of relations and inter-linkages between water availability, water usage and farmers' management practices in the study area. In the EVA pilot we approached this through a (preliminary) "exercise" by use of a network model based on Bayesian approaches. Our point-of departure/assumption was that the Bayesian approach would allow for an integrated approach to impacts and vulnerability, integrating different types of information and data e.g. qualitative information from focus groups, monitoring data (drought, rainfall, wells, etc.), management practices, household survey information, stakeholder observations, etc. and that it also could offer a good possibility to communicate and show the inter-linked results.

Bayesian networks (BN) are probabilistic graphical models, which are widely used for knowledge representation, integrated modeling and reasoning under uncertainty. They allow displaying relationships between variables ("nodes" in the BN) even though the mathematical relationship is uncertain. Arrows lead from parental nodes to child nodes indicating the causality of the relationship. The relationships between nodes are described by conditional probability distributions that encompass the dependences between variables. Another advantage is, that different types of variables (e.g. biophysical and socio-economic) and knowledge from various sources can be integrated in a single framework (Jensen 1996). Probabilistic information can be derived from measured data sets, model simulations and expert opinion (Barton et al. 2008). Due to the given characteristics the EVA-team considered BN as a useful tool for exploring and displaying the factors and relationships relating to drought and community-based adaptation options in Jalna, Maharashtra.

The development process of Bayesian networks can be split up in two main processes: (i) first, the development of the network by identifying the most important variables and the links between them, and second the population of the network with data / probability tables. The results of the first step will be a graphical presentation of the network, which is already useful in communication with stakeholders. (ii) The second step is more difficult due to often lack of data, but only this step enables to run the model. The crucial point of the first stage is to find a balance between including enough nodes to both display and model complex relationships, but at the same time ensure not to make the model too complex by including too many nodes. Furthermore, the number of parental nodes should be limited to three to four, as otherwise the filling of the conditional probability tables is very difficult. As the EVA-project was design as pilot project, the project team conducted only the first step and designed a graphical representation of the most important factors influencing drought occurrence and community-based adaptation in Jalna. The model was filled with data mainly gather through a workshop among the local project participants (expert knowledge) and the gathered data during field work and reporting.

When designing the BN, we focused at this time on the single household level, as the future aim for the BN model is to assess single household drought risk. Therefore given the status of certain factors (parental nodes) as e.g. geology, area of farm land, rainfall in the last years, household income, etc. we wanted to know the probability that this household is at risk for certain types of drought, including socio-economic drought.

The genesis of drought and (community-based) adaptation to it is a complex process. While for the occurrence of meteorological, hydrological and agricultural drought mainly climatic, geologic and biologic factors play a role, for the occurrence of socio-economic droughts are also social and economic factors important. As endpoints for the BN we defined 4 discrete Boolean nodes (false/true), which give a probability that this type of drought will/has commence given a certain probability of the parental nodes.

The presented Bayesian Network below is to be considered a preliminary one. Given the pilot character of EVA, the project team ended up with the first step of creating BNs and uses the network for visualization and dialogue purposes. The network (see figure below) displays the most important natural-scientific factors, but has truly certain deficits concerning different community based adaptation options. Further the number of parental nodes to certain child nodes (e.g. Agricultural Yield) should be limited before starting with the second step. The colors in the presented BN were used for visualization purposes, but do not have any meaning for the model itself. Blue-colored nodes indicate that these factors are water-related, green nodes connotate agricultural factors, yellow are individual household related factors and brown are external factors.

Meteorological drought is defined as a deficit in rainfall, thus the only parental node to meteorological drought is monsoon precipitation. Hydrological drought is defined as a deficit flow in surface water bodies, as well as in groundwater. Thus parental nodes for hydrological drought are deep groundwater and surface water. These water sources can be considered as independent, i.e. deep groundwater is not feeding surface water bodies. There is no direct arrow between shallow groundwater and hydrological drought in the network model, as the shallow groundwater bodies mostly feed surface water bodies and thus cause hydrological drought via surface water deficits.

Agricultural drought is defined as soil water deficit leading to reduced crop production. The factors calling for meteorological and hydrological drought proceed indirectly in the network to agricultural drought via irrigation and soil moisture status, which are defined as parental nodes to agricultural drought. Socio-economic drought is the most complex type of drought. In the EVA-project we defined it as "critical livelihood situation" on single household level, meaning that households were affected by drought in a way that would influence their current life status, significantly diminish their income, endanger the education possibilities of children or even household members health e.g. due to malnutrition (see EVA WP3.1 report on issues related to socio-economic drought).

Agricultural yield can be considered as the most important factor influencing socio-economic drought, even though there is no direct arrow between them. But agricultural yield determines the production of self-sufficient household food and the income from farming. The first one is considered as direct parental node to socio-economic drought, while the income from farming contributes to the total income, which is linked to socio-economic drought. At the level of socio-economic drought also external factors as crop prices and world markets play a role, but also the economic situation of the household, which was also found to be determined by the caste.

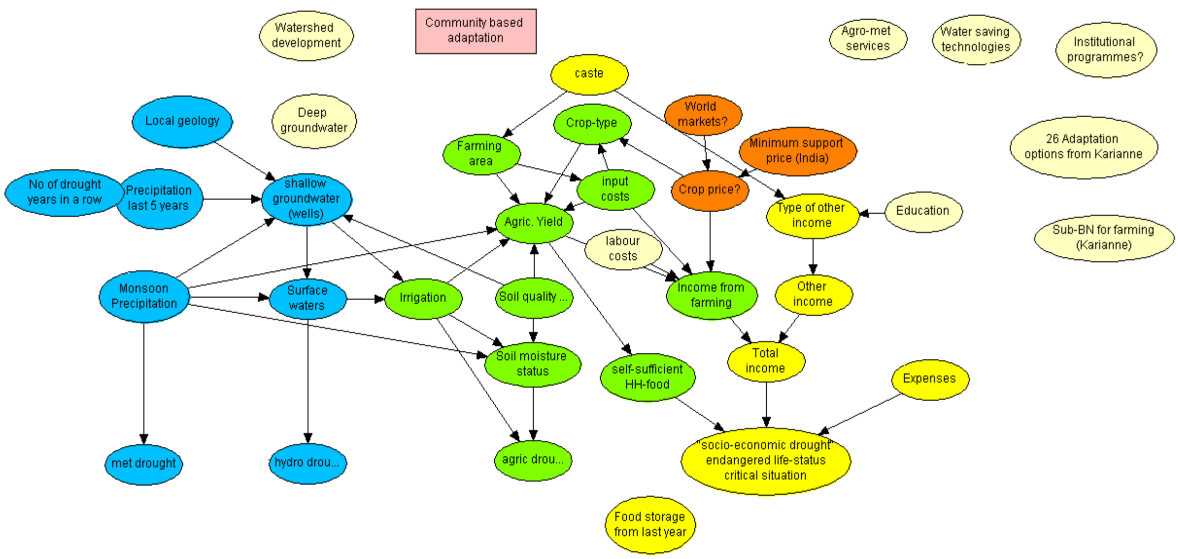


Figure 15. Bayesian network of drought

In the pilot we only briefly worked with the Bayesian Network approach, thus more work would be needed to make final conclusions and evaluation. We found preliminary, that the Bayesian Network can be considered as a useful tool for visualization of different factors influencing the genesis of different types of droughts. In a follow-up activity/project it should be aimed to better integrate community-based adaptation, improve the network design and aim for the second step (filling the network with data).

5.3 Water resources and future pressures

Building on the findings on future climate change in the study area (see EVA WP1) and the participatory workshops where participants listed expected impacts, in particular for agriculture, of the presented climate change scenarios we can make some reflections on future pressures on water and agriculture resources. The workshop participants in particular listed the following impacts: decrease in *rabi* yield, increase in irrigation requirement of *kharif* crop, decline in agricultural labour opportunities/wages, adverse impact on orchards, increase in pest attacks, scarcity of fodder and water for livestock.

Analysis of past data (2004-2011) revealed a declining trend of rainfall during monsoons in the district. However, analysis of past 27 years data (1984-2011) for Badnapur showed that while the rainfall during June and July have been decreasing, the rainfall during August and September months show an increase. In the future however, an increase in extreme wet days and extreme rainfall over Jalna and the Marathwada region as a whole is projected (see EVA WP1 report).

During the participatory workshops the participants listed potential adaptation options related to agriculture: changes in cropping practices; switch to fodder crops and introduce short duration crops, for water harvesting: establishing farm ponds, and KT weirs, (individual vs collective), and for water conservation and efficiency: introduce drip and/or sprinkler irrigation. Soil conservation and enrichment through farm bunds were also put forward due to the importance of soil conditions both for agriculture and water (see EVA WP4 report for details on adaptation options).

Adaptation responses to deal with climate change impacts on both the water resources and the communities depend on the adaptive capacity of the communities. Which capacities that are build and measures adapted is also about learning to live with risks and variability. In the communities of the Jalna District there are other pressures on the water resources than just climatic extremes and climate change, e.g. economic and population changes. Hence, climate change aspects need to be considered as part of all development initiatives/projects and vice versa. Integrating adaptation into development projects is the process of identifying climate related risks and adjusting activities/approaches to reduce such risks. This is a way to strive to minimise the likelihood of climate change undermining or negating the effectiveness and sustainability of development interventions. Such considerations were addressed as part of the EVA-project capacity building activates (see EVA WP5 report).

6 Conclusions

The communities in Jalna are strongly attached to their natural resources, and water resources are at the core of their livelihood through agriculture. The main water uses are for drinking and agriculture. The area is part of a dryland ecosystem with a semi-arid climate, where most of the rainfall comes during the monsoon months (June-September). The communities are thus strongly dependent on the monsoon rain in their livelihood, which also influences the water resources management.

Water-intensive cash crops like cotton are an important part of the livelihood base in the nine villages. Much of the agriculture is rain fed, private dug wells for irrigation are a dominant and irrigation often happens through flooding of the fields. There is still relatively little drip irrigation in the region, yet more and more farmers are also starting to install and use drip irrigation. Drip irrigation is considered among the most relevant technical adaptation options to preserve and use water more efficiently in agriculture.

In terms of watershed structures, there seemed to be less sense of ownership and engagement around collective water structures than individual ones. In particular the lack of maintenance of collective watershed structures is an issue, which leaves some structures suffering from lack of de-silting and hence not fully contributing as intended to water resources management.

The availability of groundwater in the area is uneven, both in space, time, and depth. The uneven distribution can be mainly attributed to the highly heterogeneous lithology and regional variation of rainfall. The hydrogeology in the area is complex with basaltic rock and shallow aquifers. The complexity makes it both challenging to study and to manage. Due to complex hydrogeology with mainly shallow aquifers, localized variations occur. The shallow aquifers are strongly affected by changes in rainfall.

During the 2012-2013 drought, the region was strongly affected in terms of impacts on agriculture and water resources. With a "failing" monsoon the water resources available are strongly affected, and most of the open dug wells were dry during the field visit in September 2012. Jalna District received less than 50 % of the average normal rainfall in 2012. There were however differences within the region and the impacts of the drought were not only caused by lack of rain, but also management of the resources. Several watershed structures, such as check-dams, were reported as non-functional due to lack of maintenance, which can add to the vulnerability of the system.

The communities reported on local experiences variances in drought impacts and vulnerability of water and agricultural resources relating to both natural conditions and marked-related aspects. The process of participatory drought mapping in the villages demonstrated that drought, as experienced phenomenon, goes beyond meteorological drought and farmers in particular noted concerns related to soil resources and its impact on water and agriculture. Thus, looking into aspects of both agriculture (soil moisture), hydrological (water resources, wells) and socio-economic drought (differences in access/impacts) is important when considering community-based adaptation to drought. Scarce data, especially at local scale, is a constraint for detailed hydrological mapping, planning, and impact monitoring.

While there is disparity in water availability for irrigation within communities in the region, availability of drinking water is normally assured by the government. In the nine villages of the study, water tankers can as of now be seen as 'a part of the ecosystem' as they are providing water during dry months. E.g. all the villages in the Badnapur block, reported that tankers had been coming regularly to the villages during the dry months since the last five years. The drought of 2012–13 was also noted a 'drinking water drought', and the tanker schemes were intensified both with governmental and private tankers. Although drinking water could be provided, this may also be taken as a note of warning for the future. In the context of climate change, which may put more pressure on already stressed resources and livelihood situations, cautious considering of water uses (which purpose and crops etc.) and how to best manage and govern the water resources is of high importance.

Policy implications based on our findings:
Watershed planning: Planning of decentralized watershed infrastructure should resonate with the complex hydrogeology of the region in order to ensure equitable benefits for local communities and sustainable ecosystems. Maintenance of structures should be prioritized.

Soil management and irrigation: Continuous focus on soil management and farming techniques to conserve water, soil, and nutrients is needed. Support and training for water budgeting and use of drip and sprinkler irrigation technologies for efficient use of scarce water resources should be provided.

Improved monitoring: Denser networks of monitoring stations at the local scale are required for better understanding of drought status, scale, and impacts. Engagement of local communities in operation and maintenance of monitoring systems can help in improving resource and drought management. It can also help farmers in planning and decision-making.

Research on agriculture and livelihood diversification: Adapting to climate change requires adjustment in existing livelihood strategies beyond 'business as usual' strategies. There might be a need to diversify types of crops grown and livelihood activities for sustainable development. Research and innovation in this area should be supported.

Strengthen policy and institutional framework: Climate change is not limited to any one sector alone. There is a need to facilitate multi-sector and integrated approaches to managing climate change and variability across all sectors.

Increase conceptual awareness: Success of climate change adaptation would depend on multi-level stakeholders' understanding of the causes of vulnerability and the implications of water- and agriculture-related management practices that are adopted.

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Annex

EVA Well survey

The EVA Wells have ID after the village in which they are located. Six wells have been surveyed in each village.

Elevation and location of wells were mapped with GSP. We have chosen to not include the exact coordinates in the report; the coordinates are kept with the project team for reference and possible follow-up studies.

Measurements were done in feet, and then converted to meters. Diameter and water depths were measured with measuring tape. The remaining information is based on interviews with the well owners.

EVA Well survey: meta data about the wells

All wells are **open dug wells**

Well ID	elevation (m.a.s.l)	Total well depth (m)	Well diameter (m)	Approx. year of construction	Village	Block	*Approx.* total area irrigated by well (acres)	No of farmers/ pers. normally using well	Primary water use	Secondary water use **	Irrigation: Flooding	Irrigation : Drip	Irrigation: Sprinkler	Main crops irrigated by well in Kharif, normally	Main crops irrigated by well in Rabi, normally *	Well usually receives tanker water?
PB1	565	13.7	6.1	2010	Pimplegaon Barav	Bhokhardhan	16	1	Irrigation	domestic (2012)	yes	no	yes	cotton, maize, mycho seed, (bajra/tur)	jowar	no
PB2	553	15.2	7.0	2009	Pimplegaon Barav	Bhokhardhan	7.5	1	Irrigation	domestic	yes	no	no	cotton, maize, mycho seed, (tur)	jowar, ginger	no
PB3	560	12.2	4.6	1970	Pimplegaon Barav	Bhokhardhan	12	1	Irrigation	domestic	yes	yes	no	cotton, maize, tur	wheat, jowar	no
PB4	566	10.7	9.1	1983	Pimplegaon Barav	Bhokhardhan	18	1	Irrigation	*none given*	yes	no	yes	cotton, maize, soya bean, (tur)	jowar, wheat	no
PB5	556	12.2	9.4	1970	Pimplegaon Barav	Bhokhardhan	15	1	Irrigation	*none given*	yes	no	yes	cotton, maize	jowar, wheat	no
PB6	575	10.7	5.5	1960	Pimplegaon Barav	Bhokhardhan	8	4	Irrigation	*none given*	yes	no	no	cotton, maize, tur	jowar, channa	no
TP1	604	15.2	5.5	1952	Thote Pimplegaon	Bhokhardhan	3	1	Irrigation	none given	yes	no	no	cotton, soya bean, maize	cotton*, jowar	no
TP2	608	15.5	7.0	1972	Thote Pimplegaon	Bhokhardhan	9	1	Irrigation	domestic	yes	yes	yes	cotton, soya bean, maize	cotton*, jowar	no
TP3	587	15.2	6.7	1989	Thote Pimplegaon	Bhokhardhan	10	1	Irrigation	domestic	yes	yes	no	cotton, maize, soya bean	cotton*, jowar	yes
TP4	601	15.2	6.7	1977	Thote Pimplegaon	Bhokhardhan	2	1	Irrigation	domestic	yes	no	no	cotton, maize	cotton *, jowar	no

TP5	594	15.2	6.1	2005	Thote Pimplegaon	Bhokhardhan	3	1	Irrigation	domestic	yes	no	no	cotton seed, mug, maize, sugar cane	jowar	no
TP6	593	10.7	6.1	1977	Thote Pimplegaon	Bhokhardhan	4	1	Irrigation	domestic	yes	yes	no	cotton/tur, maize, bajra	jowar	no
PP1	572	12.2	5.5	2009	Palaskheda Pimple	Bhokhardhan	18	1	Irrigation	domestic	yes	yes	no	cotton, maize	cotton *, jowar	no
PP2	583	16.8	5.8	2007	Palaskheda Pimple	Bhokhardhan	3.75	1	Irrigation	domestic	yes	yes	no	cotton, soya bean	jowar	no
PP3	569	10.7	3.4	1940	Palaskheda Pimple	Bhokhardhan	11	1	Irrigation	domestic (salty water)	yes	no	yes	cotton, bajra, soya bean	jowar, wheat	no
PP4	562	10.7	4.9	2002	Palaskheda Pimple	Bhokhardhan	4	1	Irrigation	domestic	yes	no	no	cotton, bajra, ginger	cotton*, Wheat	no
PP5	570	12.2	5.5	1963	Palaskheda Pimple	Bhokhardhan	4.5	1	Irrigation	domestic	yes	no	no	cotton, maize, soya bean	cotton*, jowar	no
PP6	576	13.7	6.7	1987	Palaskheda Pimple	Bhokhardhan	6	1	Irrigation	domestic	yes	no	no	cotton, maize, soya bean, mug	jowar	yes
A1	600	9.8	7.3	1985	Asarkheda	Badnapur	15	1	Irrigation	domestic	yes	no	no	cotton, maize	cotton*, wheat	no
A2	596	12.2	6.1	1970	Asarkheda	Badnapur	5	1	Irrigation	domestic	yes	no	no	cotton, maize	cotton*, jowar	no
A3	592	12.2	7.9	1973	Asarkheda	Badnapur	9	1	Irrigation	domestic	yes	no	no	cotton, mug	cotton*, jowar	no
A4	594	11.9	5.5	1992	Asarkheda	Badnapur	10	1	Irrigation	domestic	yes	no	no	cotton, bajra	cotton*, jowar	no
A5	604	11.0	5.5	2002	Asarkheda	Badnapur	4.5	1	Irrigation	domestic	yes	no	no	cotton, bajra	cotton*, jowar	no
A6	608	8.2	4.9	1972	Asarkheda	Badnapur	2.75	1	Irrigation	domestic	yes	no	no	soya bean, cotton, maize	jowar	no

D1	606	11.6	6.1	1980	Dongaon	Jafrabad	20	4 brothers	Irrigation	domestic	yes	yes	no	cotton, maize, mug, soya bean	cotton*, jowar	yes
D2	616	10.7	6.7	1985	Dongaon	Jafrabad	8	1	Irrigation	domestic	yes	yes	no	cotton, maize, bajra	jowar	no
D3	589	12.2	4.9	1992	Dongaon	Jafrabad	2.75	1	Irrigation	domestic	yes	yes	no	cotton, maize	jowar	no
D4	597	10.7	8.8	1995	Dongaon	Jafrabad	7.5	3 brothers	Irrigation	domestic	yes	no	no	cotton, maize, bajra	cotton*, jowar	no
D5	591	12.2	9.1	1972	Dongaon	Jafrabad	18	3 brothers share it	Irrigation	*none given*	yes	yes	no	cotton, maize, mug, tur	jowar	no
D6	582	8.2	3.7	1945	Dongaon	Jafrabad	18	12 people share it	Irrigation	domestic	yes	yes	no	cotton, maize, mug, bajra	cotton*, jowar	no
N1	606	14.6	6.1	1992	Niwdunga	Jafrabad	11.5	1	Irrigation	household	yes	yes	no	cotton, mung, soya bean, ginger	jowar	no
N2	618	10.7	6.7	1986	Niwdunga	Jafrabad	8	1	Irrigation	domestic	yes	yes	yes	cotton, maize	jowar	no
N3	614	7.9	4.6	1980	Niwdunga	Jafrabad	2.5	1	Irrigation	domestic	yes	no	no	cotton	cotton*, jowar	no
N4	608	12.2	6.9	1990	Niwdunga	Jafrabad	11	1	Irrigation	domestic	yes	no	no	cotton, maize	cotton*, jowar	no
N5	589	16.8	7.9	1980	Niwdunga	Jafrabad	10	1	Irrigation	domestic	yes	yes	no	cotton, maize, mirchi, brinjol	jowar, channa	no
N6	597	10.7	6.1	1994	Niwdunga	Jafrabad	30	1	Irrigation	domestic	yes	no	yes	cotton, mize, mug, soya bean	jowar	no
M1	537	19.8	6.1	1981	Malegaon	Badnapur	2.5	1	Irrigation	domestic	yes	yes	no	cotton and orange	cotton*	no

M2	536	15.5	4.6	1972	Malegaon	Badnapur	1.5	5 brothers	Irrigation	*none given*	yes		no	cotton	cotton*	yes
M3	516	19.8	3.7	1990	Malegaon	Badnapur	4.0	1	Irrigation	*none given*	yes	yes	no	orange and cotton	orange , cotton*	no
M4	509	15.5	6.1	1992	Malegaon	Badnapur	3.5	1	Irrigation	drinking water	yes	yes	no	cotton	cotton*	no
M5	522	9.1	6.1	1972	Malegaon	Badnapur	4.0	1	Irrigation	domestic use	yes		no	cotton, bajra, tur	cotton*	no
M6	525	21.9	6.7	1990	Malegaon	Badnapur	4.0	1	Irrigation	drinking water *	yes	yes	no	orange, cotton	orange, cotton*	no
W1	544	18.3	6.1	1985	Warudi	Badnapur	14	3 brothers)	Irrigation	domestics	no	yes	no	cotton, maize	channa	yes
W2	541	21.3	5.5	1960	Warudi	Badnapur	10	2 brothers	Irrigation	domestic	no	yes	no	cotton, maize, bajra	cotton, jowar	no
W3	536	15.2	5.5	1965	Warudi	Badnapur	15	1	Irrigation	domestic	no	yes	no	cotton, maize	jowar, channa (Bengal gram)	no
W4	539	12.8	8.2	1950	Warudi	Badnapur	24.5	5 brothers	Irrigation	*none given*	yes	yes	no	cotton, maize and bajra	jowar	no
W5	536	15.2	6.1	1985	Warudi	Badnapur	?	1	Irrigation	domestic	yes	yes	no	cotton, maize and bajra	jowar	yes
W6	535	20.7	3.7	1970	Warudi	Badnapur	3	1	Irrigation	*none given*	yes		no	cotton and maize	cotton*, jowar	no
K1	527	15.2	6.1	2000	Kadegaon	Badnapur	15	1	Irrigation	domestic	No	Yes	Yes	cotton, bajra, maize, tur	jowar, channa (Bengal gram)	no
K2	531	15.2	4.9	1987	Kadegaon	Badnapur	6	1	irrigation	Domestic mainly drinking.	Yes	Yes	no	cotton, maize, bajra	cotton*, wheat, jowar	no

K3	527	12.2	5.3	1987	Kadegaon	Badnapur	7	1	Irrigation	domestic	Yes	Yes	no	cotton, bajra, orange	channa (bengal gram), wheat	yes
K4	531	21.3	6.1	1985	Kadegaon	Badnapur	30	1	Irrigation	*none given*	yes	yes	no	cotton, maize,bajra	cotton*, jowar	no
K5	525	18.3	6.7	1993	Kadegaon	Badnapur	5	1	Irrigation	domestic	yes	yes		cotton, maize,bajra	cotton*, jowar, channa	no
K6	524	15.2	4.0	1985	Kadegaon	Badnapur	5	1	Irrigation	domestic	yes		yes	maize, bajra,tur, cotton	wheat, jowar	yes
Average	**569**	**14**	**6**	**1982**												
Median	**574**	**12**	**6**	**1985**												

* Cotton is not cultivated in Rabi season, but it is a long duration crop and sometimes due to delayed flowering or monsoon, it stands in Rabi season. However the sowing is done in Kharif only. Generally cotton harvesting/picking continues till February. So, when the farmers has given Cotton as a crop for Rabi, it refers the cotton from the previous Kharif season

** Domestic basically refers to use of water by the farmer and labors for cleaning, washing and drinking purpose when they work in the field. Farmers are not fetching water from wells to the villages or their home for any purpose. It happens only in the exceptional cases if there is acute shortage or non availability of DW in the habitation from their regular source or supply non availability of DW in the habitation from their regular source or supply

Pumping data next page:

Pumping rate is calculated by measuring the actual discharge from the pump outlet and with the discussion with farmer.
The number of pumping days is calculated based on the following formula: {Number of Pumping days = days to maturity for the particular crop /Irrigation interval for that particular season}

Irrigation interval is calculated on the basis of discussion with the individual well owners, the irrigation intervals for the seasons are as follow:
Karif: 8days; Rabi: 6days and summer: 4 days.

The Approximate pumping hours per pumping days in Karif, Rabi and summer were individually noted from the farmers.

Information on pumping from wells:

Well ID	Pump type (if any)	Pump capacity (HP)	Pumping rate (rate of water drawn) (litre /min)	Approx. no of *pumping days* in Kharif	Approx. pumping hours per pumping day in Kharif (hours)	Approx. no of pumping days in Rabi	Approx. pumping hours per pumping day in Rabi (hours)	Approx. no of pumping days in Summer (April+May) for drinking water	Approx. no of pumping days in Summer for irrigation	Approx. pumping minutes per pumping day in Summer for drinking (min)	Approx. pumping hours per pumping day in Summer for irrigation (hours)
PB1	*not specified*	3	100/min	53	4	53	8	60	0	5	0
PB2	Submersible	3	125/min	53	2	70	6	60	0	5	0
PB3	kupal set	3	143/min	53	3.5	70	7	60	0	30	0
PB4	Submersible	5	200/min	53	5	70	9	60	30	30	2
PB5	Submersible	5	80/min	30	4	40	8	60	0	3	0
PB6	Submersible	5	200/min	53	4	70	7	60	30	30	2
TP1	Submersible	3	250/min	30	3	40	6	60	0	15	0
TP2	Submersible	5	300/min	30	5	40	8	60	0	5	0
TP3	Monoblock	3	140/min	30	5	40	8	60	0	5	0
TP4	Monoblock	3	100/min	30	4	40	9	60	0	5	0
TP5	Submersible	3	100/min	30	4	40	6	60	0	5	0
TP6	Submersible	3	100/min	30	4	40	8	60	0	5	0
PP1	Oil pump	8	50/min	30	5	40	9	60	0	10	0
PP2	Submersible	5	100/min	30	3	40	9	60	0	5	0
PP3	kupal	3	200/min	30	4	40	8	60	0	15	0
PP4	submersible	3	133/min	30	6	40	8	60	0	2	0
PP5	Submersible	3	100/min	30	4	40	9	60	0	5	0
PP6	Monoblock	3	140/min	30	3	40	9	60	0	5	0
A1	Submersible	3	200/min	30	4	40	7	60	0	2	0
A2	Mono klup	3	180/min	30	4.5	40	7	60	0	2	0
A3	Submersible	3	250/min	30	3	40	5.5	60	0	5	0
A4	Mono klup	3	250/min	30	3	40	6	60	0	5	0
A5	Submersible	5	180/min	30	4	40	6	60	0	10	0
A6	Submersible	5	250/min	30	3	40	7	60	0	2	0
D1	Mono block	3	180/min	30	3	40	7	60	0	10	0

D2	Diesel engine	8	100/min	30	4	40	8	60	0	5	0
D3	Mono block	3	200/min	30	2	40	5	60	0	5	0
D4	Mono block	3	225/min	30	3	40	6	60	0	5	0
D5	Submersible	3	100/min	30	3	40	6	60	0	2	0
D6	Sub / mono	3 + 3	180/min	30	3.5	40	7	60	0	5	0
N1	Submersible	5	200/min	60	3	70	6	60	0	15	0
N2	Diesel engine	10	100/min	30	4	40	7	60	0	5	0
N3	Diesel engine	5	200/min	30	3	40	5	60	0	5	0
N4	Disel sub	5	300/min	30	1	40	5	60	0	5	0
N5	Sub	3	180/min	30	3	40	7	60	0	5	0
N6	Sub	3	180/min	30	4	40	6	60	0	5	0
M1	submersible	5	200/min	30	4	45	6	60	15	5	2
M2	mono block	3	200/min	15	3	4	6	60	0	5	0
M3	submersible	5	225/min	30	4.5	45	6	60	15	5	2
M4	submersible	5	250/min	15	3	4	6	60	0	2	0
M5	submersible	3	200/min	30	3	40	6	60	0	5	0
M6	submersible	5	200/min	30	4	15	7	60	15	5	2
W1	mono block	3	200/min	30	4	40	8	60	0	30	0
W2	mono block	3	100/min	45	6	40	8	60	0	20	0
W3	mono block	3	280/min	30	4	60	6	60	0	2	0
W4	submersible	3	180/min	30	5	45	6	60	0	2	0
W5	mono block	3	190/min	30	4	45	7	60	0	5	0
W6	mono block	3	190/min	15	6	30	7	60	0	5	0
K1	submersible	5	100/min	30	5	45	8	60	0	5	0
K2	submersible	3	200/min	45	6	80	10	60	15	5	3
K3	submersible	5	200/min	30	6	45	8	60	15	5	2
K4	submersible	5	100/min	45	6	30	8	60	15	20	2
K5	mono block	3	100/min	30	4	45	6	60	0	5	0
K6	submersible	3	110/min	30	4	45	6.5	60	0	5	0

Well water level measurements (height of water column in well) (meter): December 2012 – May 2013

	DEC 2012		JAN 2013		FEB 2013		MARCH 2013		APRIL 2013		MAY 2013	
Well ID	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)
PB1	19.12.12	0.3	16.01.13	0.3	17.02.13	0.2	16.03.13	0.2	18.04.13	0.2	16.05.13	Dry
PB2	19.12.12	0.3	16.01.13	0.3	17.02.13	0.3	16.03.13	0.3	18.04.13	0.3	16.05.13	0.3
PB3	19.12.12	6.1	16.01.13	5.5	17.02.13	5.5	16.03.13	4.6	18.04.13	4.6	16.05.13	4.0
PB4	19.12.12	0.9	16.01.13	0.9	17.02.13	0.9	16.03.13	0.9	18.04.13	0.8	16.05.13	0.6
PB5	19.12.12	0.6	16.01.13	0.6	17.02.13	0.6	16.03.13	0.5	18.04.13	0.3	16.05.13	Dry
PB6	19.12.12	1.2	16.01.13	1.1	17.02.13	1.1	16.03.13	0.9	18.04.13	0.9	16.05.13	0.8
TP1	31.12.12	0.3	16.01.13	0.3	18.02.13	0.3	17.03.13	0.2	20.04.13	0.2	16.05.13	Dry
TP2	31.12.12	4.6	16.01.13	4.6	18.02.13	4.6	17.03.13	4.1	20.04.13	4.1	16.05.13	3.4
TP3	31.12.12	0.9	16.01.13	0.9	18.02.13	0.8	17.03.13	0.8	20.04.13	0.6	16.05.13	0.5
TP4	31.12.12	1.8	16.01.13	1.8	18.02.13	1.5	17.03.13	1.5	20.04.13	1.7	16.05.13	1.2
TP5	31.12.12	1.8	16.01.13	1.8	18.02.13	1.7	17.03.13	1.7	20.04.13	1.5	16.05.13	1.4
TP6	31.12.12	1.2	16.01.13	1.2	18.02.13	1.2	17.03.13	1.1	20.04.13	1.1	16.05.13	0.6
PP1	21.12.12	0.3	17.01.13	0.3	19.02.13	0.3	18.03.13	0.2	20.04.13	0.2	16.05.13	Dry
PP2	21.12.12	3.0	17.01.13	3.0	19.02.13	2.9	18.03.13	2.9	20.04.13	2.4	16.05.13	2.1
PP3	21.12.12	Dry	17.01.13	Dry	19.02.13	Dry	18.03.13	Dry	20.04.13	Dry	16.05.13	Dry
PP4	21.12.12	0.9	17.01.13	0.9	19.02.13	0.8	18.03.13	0.8	20.04.13	0.6	16.05.13	0.5
PP5	21.12.12	0.2	17.01.13	0.2	19.02.13	0.2	18.03.13	Dry	20.04.13	Dry	16.05.13	Dry
PP6	21.12.12	1.5	17.01.13	1.5	19.02.13	1.5	18.03.13	1.5	20.04.13	1.2	16.05.13	0.9
A1	21.12.12	0.2	15.01.13	0.2	17.02.13	0.2	17.03.13	Dry	19.04.13	Dry	18.05.13	Dry
A2	21.12.12	Dry	15.01.13	Dry	17.02.13	Dry	17.03.13	Dry	19.04.13	Dry	18.05.13	Dry
A3	21.12.12	4.6	15.01.13	3.7	17.02.13	3.7	17.03.13	3.0	19.04.13	3.0	18.05.13	3.0
A4	21.12.12	1.2	15.01.13	1.2	17.02.13	1.1	17.03.13	0.9	19.04.13	0.9	18.05.13	0.6
A5	21.12.12	0.5	15.01.13	0.3	17.02.13	0.3	17.03.13	0.3	19.04.13	0.2	18.05.13	Dry
A6	21.12.12	0.3	15.01.13	0.3	17.02.13	0.2	17.03.13	0.2	19.04.13	Dry	18.05.13	Dry
D1	21.12.12	0.2	16.01.13	0.2	17.02.13	Dry	18.03.13	Dry	18.04.13	Dry	19.05.13	Dry

D2	21.12.12	0.5	16.01.13	0.5	17.02.13	0.3	18.03.13	0.2	18.04.13	0.2	19.05.13	0.2
D3	21.12.12	1.5	16.01.13	1.5	17.02.13	1.5	18.03.13	1.4	18.04.13	1.2	19.05.13	1.2
D4	21.12.12	0.8	16.01.13	0.6	17.02.13	0.6	18.03.13	0.5	18.04.13	0.3	19.05.13	0.2
D5	21.12.12	0.6	16.01.13	0.6	17.02.13	0.3	18.03.13	0.3	18.04.13	0.2	19.05.13	0.2
D6	21.12.12	0.5	16.01.13	0.5	17.02.13	0.5	18.03.13	0.3	18.04.13	0.3	19.05.13	Dry
N1	21.12.12	Dry	16.01.13	Dry	18.02.13	Dry	19.03.13	Dry	19.04.13	Dry	20.05.13	Dry
N2	21.12.12	0.8	16.01.13	0.8	18.02.13	0.6	19.03.13	0.5	19.04.13	0.3	20.05.13	0.2
N3	21.12.12	0.5	16.01.13	0.3	18.02.13	0.3	19.03.13	0.2	19.04.13	0.2	20.05.13	Dry
N4	21.12.12	3.0	16.01.13	3.0	18.02.13	3.0	19.03.13	2.4	19.04.13	2.4	20.05.13	1.8
N5	21.12.12	2.1	16.01.13	1.5	18.02.13	1.5	19.03.13	1.5	19.04.13	1.1	20.05.13	1.1
N6	21.12.12	1.5	16.01.13	1.5	18.02.13	1.1	19.03.13	1.1	19.04.13	0.6	20.05.13	0.6
M1	21.12.12	Dry	18.01.13	Dry	16.02.13	Dry	17.03.13	Dry	17.04.13	Dry	16.05.13	Dry
M2	21.12.12	0.3	18.01.13	0.3	16.02.13	0.2	17.03.13	0.2	17.04.13	Dry	16.05.13	Dry
M3	21.12.12	0.2	18.01.13	0.2	16.02.13	0.2	17.03.13	0.2	17.04.13	0.2	16.05.13	0.2
M4	21.12.12	Dry	18.01.13	Dry	16.02.13	Dry	17.03.13	Dry	17.04.13	Dry	16.05.13	Dry
M5	21.12.12	Dry	18.01.13	Dry	16.02.13	Dry	17.03.13	Dry	17.04.13	Dry	16.05.13	Dry
M6	21.12.12	0.6	18.01.13	0.6	16.02.13	0.6	17.03.13	0.5	16.04.13	0.5	16.05.13	0.3
W1	21.12.12	0.8	19.01.13	0.8	16.02.13	0.6	18.03.13	0.6	16.04.13	0.6	17.05.13	0.6
W2	21.12.12	0.9	19.01.13	0.9	16.02.13	0.8	18.03.13	0.8	16.04.13	0.5	17.05.13	0.3
W3	21.12.12	Dry	19.01.13	Dry	16.02.13	Dry	18.03.13	Dry	16.04.13	Dry	17.05.13	Dry
W4	21.12.12	Dry	19.01.13	Dry	16.02.13	Dry	18.03.13	Dry	16.04.13	Dry	17.05.13	Dry
W5	21.12.12	0.9	19.01.13	0.9	16.02.13	0.8	18.03.13	0.6	16.04.13	0.6	17.05.13	0.5
W6	21.12.12	0.5	19.01.13	0.3	16.02.13	0.3	18.03.13	0.3	18.04.13	0.2	17.05.13	Dry
K1	20.12.12	0.3	20.01.13	0.3	18.02.13	0.2	19.03.13	0.2	18.04.13	Dry	18.05.13	Dry
K2	20.12.12	0.6	20.01.13	0.6	18.02.13	0.6	19.03.13	0.6	18.04.13	0.3	18.05.13	0.3
K3	20.12.12	0.3	20.01.13	0.3	18.02.13	0.2	19.03.13	Dry	18.04.13	Dry	18.05.13	Dry
K4	20.12.12	0.9	20.01.13	0.9	18.02.13	0.9	19.03.13	0.9	18.04.13	0.9	18.05.13	0.9
K5	20.12.12	0.6	20.01.13	0.6	18.02.13	0.6	19.03.13	0.5	18.04.13	0.5	18.05.13	0.3
K6	20.12.12	0.3	20.01.13	0.3	18.02.13	0.2	19.03.13	0.2	18.04.13	Dry	18.05.13	Dry

Well water level measurements (height of water column in well) (meter): June 2013 – December 2013

	JUNE 2013		JULY 2013		AUG 2013		SEP 2013		OCT 2013		NOV 2013		DEC 2013	
Well ID	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)	Date	water level (m)
PB1	18.06.13	2.7	19.07.13	5.5	19.08.13	13.1	18.09.13	13.1	20.10.13	13.1	17.11.13	12.2	21.12.13	11.6
PB2	18.06.13	0.3	19.07.13	3.4	19.08.13	6.1	18.09.13	13.7	20.10.13	13.7	17.11.13	12.8	21.12.13	12.2
PB3	18.06.13	4.0	19.07.13	5.5	19.08.13	10.7	18.09.13	12.2	20.10.13	11.9	17.11.13	11.9	21.12.13	11.9
PB4	18.06.13	4.0	19.07.13	9.1	19.08.13	10.7	18.09.13	10.7	20.10.13	10.7	17.11.13	9.8	21.12.13	9.4
PB5	18.06.13	3.0	19.07.13	3.7	19.08.13	12.2	18.09.13	12.2	20.10.13	12.2	17.11.13	11.6	21.12.13	11.6
PB6	18.06.13	0.9	19.07.13	5.5	19.08.13	10.7	18.09.13	10.7	20.10.13	10.7	17.11.13	10.4	21.12.13	9.8
TP1	15.06.13	0.9	18.07.13	6.1	20.08.13	15.2	20.09.13	15.2	19.10.13	15.2	17.11.13	15.2	20.12.13	14.6
TP2	15.06.13	3.0	18.07.13	6.7	20.08.13	10.7	20.09.13	10.7	19.10.13	10.7	17.11.13	10.1	20.12.13	10.1
TP3	15.06.13	3.0	18.07.13	6.1	20.08.13	15.2	20.09.13	15.2	19.10.13	15.2	17.11.13	14.6	20.12.13	14.6
TP4	15.06.13	5.5	18.07.13	12.2	20.08.13	15.2	20.09.13	15.2	19.10.13	15.2	17.11.13	14.9	20.12.13	14.3
TP5	15.06.13	4.6	18.07.13	5.8	20.08.13	10.7	20.09.13	15.2	19.10.13	15.2	17.11.13	13.7	20.12.13	13.4
TP6	15.06.13	5.2	18.07.13	6.7	20.08.13	10.7	20.09.13	10.7	19.10.13	10.7	17.11.13	10.7	20.12.13	10.1
PP1	16.06.13	3.0	19.07.13	4.9	21.08.13	12.2	19.09.13	12.2	20.10.13	12.2	18.11.13	11.9	19.12.13	11.9
PP2	16.06.13	3.4	19.07.13	12.2	21.08.13	15.2	19.09.13	14.6	20.10.13	15.2	18.11.13	14.6	19.12.13	13.7
PP3	16.06.13	2.1	19.07.13	5.5	21.08.13	10.7	19.09.13	10.7	20.10.13	10.7	18.11.13	10.1	19.12.13	10.1
PP4	16.06.13	2.7	19.07.13	4.0	21.08.13	9.1	19.09.13	9.1	20.10.13	9.1	18.11.13	9.1	19.12.13	9.1
PP5	16.06.13	3.4	19.07.13	7.6	21.08.13	10.7	19.09.13	12.2	20.10.13	12.2	18.11.13	10.7	19.12.13	10.7
PP6	16.06.13	5.5	19.07.13	10.7	21.08.13	12.2	19.09.13	12.2	20.10.13	12.8	18.11.13	12.2	19.12.13	11.9
A1	19.06.13	3.0	20.07.13	9.8	20.08.13	9.4	19.09.13	9.4	19.10.13	9.1	20.11.13	9.1	19.12.13	7.6
A2	19.06.13	4.9	20.07.13	11.3	20.08.13	12.2	19.09.13	11.6	19.10.13	11.6	20.11.13	11.9	19.12.13	11.6
A3	19.06.13	6.1	20.07.13	10.7	20.08.13	10.7	19.09.13	12.2	19.10.13	12.2	20.11.13	10.7	19.12.13	10.7
A4	19.06.13	3.7	20.07.13	10.7	20.08.13	10.7	19.09.13	11.0	19.10.13	11.0	20.11.13	9.8	19.12.13	9.1
A5	19.06.13	3.0	20.07.13	7.9	20.08.13	9.1	19.09.13	9.1	19.10.13	9.1	20.11.13	8.5	19.12.13	8.8
A6	19.06.13	4.6	20.07.13	7.6	20.08.13	7.6	19.09.13	7.6	19.10.13	7.6	20.11.13	7.6	19.12.13	7.6
D1	19.06.13	7.6	18.07.13	11.6	19.08.13	11.6	18.09.13	11.6	19.10.13	10.7	18.11.13	10.7	18.12.13	9.1

D2	19.06.13	9.1	18.07.13	10.7	19.08.13	10.7	18.09.13	10.7	19.10.13	10.1	18.11.13	9.8	18.12.13	10.1
D3	19.06.13	10.7	18.07.13	12.2	19.08.13	12.2	18.09.13	12.2	19.10.13	11.6	18.11.13	12.2	18.12.13	11.0
D4	19.06.13	7.6	18.07.13	10.7	19.08.13	10.7	18.09.13	10.7	19.10.13	10.7	18.11.13	10.1	18.12.13	9.4
D5	19.06.13	9.1	18.07.13	12.2	19.08.13	12.2	18.09.13	11.6	19.10.13	11.9	18.11.13	11.9	18.12.13	11.0
D6	19.06.13	8.2	18.07.13	8.2	19.08.13	8.2	18.09.13	8.2	19.10.13	8.2	18.11.13	7.3	18.12.13	7.3
N1	18.06.13	3.4	20.07.13	6.1	21.08.13	12.2	20.09.13	12.2	20.10.13	12.2	19.11.13	11.6	18.12.13	12.2
N2	18.06.13	2.7	20.07.13	6.7	21.08.13	10.7	20.09.13	10.7	20.10.13	10.4	19.11.13	10.7	18.12.13	10.1
N3	18.06.13	3.0	20.07.13	7.6	21.08.13	7.6	20.09.13	7.6	20.10.13	7.6	19.11.13	7.0	18.12.13	7.0
N4	18.06.13	4.3	20.07.13	9.1	21.08.13	10.7	20.09.13	12.2	20.10.13	12.2	19.11.13	11.0	18.12.13	11.0
N5	18.06.13	5.5	20.07.13	13.7	21.08.13	15.2	20.09.13	15.2	20.10.13	15.2	19.11.13	14.6	18.12.13	14.6
N6	18.06.13	3.7	20.07.13	10.7	21.08.13	10.7	20.09.13	10.7	20.10.13	10.7	19.11.13	9.8	18.12.13	9.8
M1	19.06.13	3.0	17.07.13	9.8	18.08.13	10.7	19.09.13	10.7	18.10.13	9.8	17.11.13	9.8	19.12.13	9.1
M2	19.06.13	4.9	17.07.13	12.2	18.08.13	13.7	19.09.13	13.7	18.10.13	13.1	17.11.13	13.1	19.12.13	12.2
M3	19.06.13	6.7	17.07.13	16.8	18.08.13	18.3	19.09.13	18.3	18.10.13	17.7	17.11.13	17.7	19.12.13	16.8
M4	19.06.13	4.6	17.07.13	8.5	18.08.13	9.1	19.09.13	9.1	18.10.13	9.1	17.11.13	8.5	19.12.13	7.6
M5	19.06.13	5.5	17.07.13	7.6	18.08.13	9.1	19.09.13	9.1	18.10.13	8.5	17.11.13	7.0	19.12.13	6.1
M6	19.06.13	7.6	17.07.13	15.8	18.08.13	16.8	19.09.13	16.8	18.10.13	15.8	17.11.13	15.2	19.12.13	14.6
W1	18.06.13	10.7	16.07.13	15.2	16.08.13	15.8	19.09.13	15.8	19.10.13	15.8	20.11.13	14.6	18.12.13	13.7
W2	18.06.13	7.6	16.07.13	9.1	16.08.13	11.3	19.09.13	11.3	19.10.13	11.3	20.11.13	10.7	18.12.13	9.1
W3	18.06.13	7.6	16.07.13	9.1	16.08.13	11.3	19.09.13	11.3	19.10.13	11.3	20.11.13	10.7	18.12.13	9.1
W4	18.06.13	9.1	16.07.13	12.2	16.08.13	12.2	19.09.13	11.6	19.10.13	11.9	20.11.13	11.9	18.12.13	11.0
W5	18.06.13	2.7	16.07.13	4.0	16.08.13	10.7	19.09.13	10.7	19.10.13	10.7	20.11.13	10.1	18.12.13	9.1
W6	18.06.13	3.0	16.07.13	7.9	16.08.13	9.1	19.09.13	9.1	19.10.13	9.1	20.11.13	8.5	18.12.13	8.8
K1	20.06.13	4.6	18.07.13	14.6	17.08.13	15.2	18.09.13	15.2	20.10.13	14.6	20.11.13	14.0	20.12.13	12.2
K2	20.06.13	6.1	18.07.13	13.7	17.08.13	15.2	18.09.13	15.2	20.10.13	15.2	20.11.13	14.6	20.12.13	13.7
K3	20.06.13	7.6	18.07.13	9.8	17.08.13	12.2	18.09.13	12.2	20.10.13	12.2	20.11.13	10.7	20.12.13	9.1
K4	20.06.13	9.1	18.07.13	13.7	17.08.13	16.8	18.09.13	16.8	20.10.13	16.8	20.11.13	15.2	20.12.13	13.7
K5	20.06.13	6.7	18.07.13	10.7	17.08.13	12.2	18.09.13	12.2	20.10.13	12.2	20.11.13	11.6	20.12.13	10.7
K6	20.06.13	6.1	18.07.13	10.7	17.08.13	9.1	18.09.13	9.1	20.10.13	8.5	20.11.13	8.5	20.12.13	7.6

Depth of water levels in wells (meters below ground surface). When well dry noted below the total depth. (One measurement per month as given in table above)

Well ID	Total well depth (m)	Dec 2012	Jan 2013	Feb 2013	March 2013	April 2013	May 2013	June 2013	July 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013
PB1	13.7	13.4	13.4	13.6	13.6	13.6	below 13.7	10.7	8.2	0.6	0.6	0.6	1.5	2.1
PB2	15.2	14.9	14.9	14.9	14.9	14.9	14.9	14.6	11.9	9.1	1.5	1.5	2.4	3.0
PB3	12.2	6.1	6.7	6.7	7.6	7.6	8.2	2.1	6.7	1.5	0.0	0.3	0.3	0.3
PB4	10.7	9.8	9.8	9.8	9.8	9.9	10.1	5.8	1.5	0.0	0.0	0.0	0.9	1.2
PB5	12.2	11.6	11.6	11.6	11.7	11.9	below 12.2	8.5	8.5	0.0	0.0	0.0	0.6	0.6
PB6	10.7	9.4	9.6	9.6	9.8	9.8	9.9	8.5	5.2	0.0	0.0	0.0	0.3	0.9
TP1	15.2	14.9	14.9	14.9	15.1	15.1	below 7.6	14.0	9.1	0.0	0.0	0.0	0.0	0.6
TP2	15.5	11.0	11.0	11.0	11.4	11.4	12.2	7.9	8.8	4.9	4.9	4.9	5.5	5.5
TP3	15.2	14.3	14.3	14.5	14.5	14.6	14.8	11.3	9.1	0.0	0.0	0.0	0.6	0.6
TP4	15.2	13.4	13.4	13.7	13.7	13.6	14.0	7.9	3.0	0.0	0.0	0.0	0.3	0.9
TP5	15.2	13.4	13.4	13.6	13.6	13.7	13.9	8.8	9.4	4.6	0.0	0.0	1.5	1.8
TP6	10.7	9.4	9.4	9.4	9.6	9.6	10.1	4.3	4.0	0.0	0.0	0.0	0.0	0.6
PP1	12.2	11.9	11.9	11.9	12.0	12.0	below 12.2	8.8	7.3	0.0	0.0	0.0	0.3	0.3
PP2	16.8	13.7	13.7	13.9	13.9	14.3	14.6	10.4	4.6	1.5	2.1	1.5	2.1	3.0
PP3	10.7	below 10.7	below 10.7	below 10.7	below 10.7	below 10.7	below 10.7	below 10.7	5.2	0.0	0.0	0.0	0.6	0.6
PP4	10.7	9.8	9.8	9.9	9.9	10.1	10.2	7.0	6.7	1.5	1.5	1.5	1.5	1.5
PP5	12.2	12.0	12.0	12.0			below 12.2	8.7	4.6	1.5	0.0	0.0	1.5	1.5
PP6	13.7	12.2	12.2	12.2	12.2	12.5	12.8	6.7	3.0	1.5	1.5	0.9	1.5	1.8

A1	9.8	9.6	9.6	9.6	below 9.8	below 9.8	below 9.8	6.6	0.0	0.3	0.3	0.6	0.6	2.1
A2	12.2	below 12.2	below 12.2	below 12.2	below 12.2	below 12.2	below 12.2	below 12.2	0.9	0.0	0.6	0.6	0.3	0.6
A3	12.2	7.6	8.5	8.5	9.1	9.1	9.1	1.5	1.5	1.5	0.0	0.0	1.5	1.5
A4	11.9	10.7	10.7	10.8	11.0	11.0	11.3	7.0	1.2	1.2	0.9	0.9	2.1	2.7
A5	11.0	10.5	10.7	10.7	10.7	10.8	below 11.0	7.5	3.0	1.8	1.8	1.8	2.4	2.1
A6	8.2	7.9	7.9	8.1	8.1	below 8.2	below 8.2	3.4	0.6	0.6	0.6	0.6	0.6	0.6
D1	11.6	11.4	11.4	below 11.6	below 11.6	below 11.6	below 11.6	3.8	0.0	0.0	0.0	0.9	0.9	2.4
D2	10.7	10.2	10.2	10.4	10.5	10.5	10.5	1.1	0.0	0.0	0.0	0.6	0.9	0.6
D3	12.2	10.7	10.7	10.7	10.8	11.0	11.0	0.0	0.0	0.0	0.0	0.6	0.0	1.2
D4	10.7	9.9	10.1	10.1	10.2	10.4	10.5	2.3	0.0	0.0	0.0	0.0	0.6	1.2
D5	12.2	11.6	11.6	11.9	11.9	12.0	12.0	2.4	0.0	0.0	0.6	0.3	0.3	1.2
D6	8.2	7.8	7.8	7.8	7.9	7.9	below 8.2	0.0	0.0	0.0	0.0	0.0	0.9	0.9
N1	14.6	below 14.6	below 14.6	below 14.6	below 14.6	below 14.6	below 14.6	11.3	8.5	2.4	2.4	2.4	3.0	2.4
N2	10.7	9.9	9.9	10.1	10.2	10.4	10.5	7.2	4.0	0.0	0.0	0.3	0.0	0.6
N3	7.9	7.5	7.6	7.6	7.8	7.8	below 7.9	4.4	0.3	0.3	0.3	0.3	0.9	0.9
N4	12.2	9.1	9.1	9.1	9.8	9.8	10.4	4.9	3.0	1.5	0.0	0.0	1.2	1.2
N5	16.8	14.6	15.2	15.2	15.2	15.7	15.7	9.1	3.0	1.5	1.5	1.5	2.1	2.1
N6	10.7	9.1	9.1	9.6	9.6	10.1	10.1	5.5	0.0	0.0	0.0	0.0	0.9	0.9
M1	19.8	below 19.8	below 19.8	below 19.8	below 19.8	below 19.8	below 19.8	16.8	10.1	9.1	9.1	10.1	10.1	10.7
M2	15.5	15.2	15.2	15.4	15.4	below 9.1	below 9.1	10.4	3.4	1.8	1.8	2.4	2.4	3.4

M3	19.8	19.7	19.7	19.7	19.7	19.7	19.7	13.0	3.0	1.5	1.5	2.1	2.1	3.0
M4	15.5	below 15.5	below 15.5	below 15.5	below 15.5	below 15.5	below 15.5	below 15.5	7.0	6.4	6.4	6.4	7.0	7.9
M5	9.1	below 9.1	below 9.1	below 9.1	below 9.1	below 9.1	below 9.1	below 9.1	1.5	0.0	0.0	0.6	2.1	3.0
M6	21.9	21.3	21.3	21.3	21.5	21.5	21.6	13.7	6.1	5.2	5.2	6.1	6.7	7.3
W1	18.3	17.5	17.5	17.7	17.7	17.7	17.7	6.9	3.0	2.4	2.4	2.4	3.7	4.6
W2	21.3	20.4	20.4	20.6	20.6	20.9	21.0	12.8	12.2	10.1	10.1	10.1	10.7	12.2
W3	15.2	below 15.2	below 15.2	below 15.2	below 15.2	below 15.2	below 15.2	below 15.2	6.1	4.0	4.0	4.0	4.6	6.1
W4	12.8	below 12.8	below 12.8	below 12.8	below 12.8	below 12.8	below 12.8	below 12.8	0.6	0.6	1.2	0.9	0.9	1.8
W5	15.2	14.3	14.3	14.5	14.6	14.6	14.8	11.6	11.3	4.6	4.6	4.6	5.2	6.1
W6	20.7	20.3	20.4	20.4	20.4	20.6	below 20.7	17.2	12.8	11.6	11.6	11.6	12.2	11.9
K1	15.2	14.9	14.9	15.1	15.1	below 15.2	below 15.2	10.4	0.6	0.0	0.0	0.6	1.2	3.0
K2	15.2	14.6	14.6	14.6	14.6	14.9	14.9	8.5	1.5	0.0	0.0	0.0	0.6	1.5
K3	12.2	11.9	11.9	12.0	below 12.2	below 12.2	below 12.2	4.3	2.4	0.0	0.0	0.0	1.5	3.0
K4	21.3	20.4	20.4	20.4	20.4	20.4	20.4	11.3	7.6	4.6	4.6	4.6	6.1	7.6
K5	18.3	17.7	17.7	17.7	17.8	17.8	18.0	11.0	7.6	6.1	6.1	6.1	6.7	7.6
K6	15.2	14.9	14.9	15.1	15.1	below 15.2	below 15.2	8.8	4.6	6.1	6.1	6.7	6.7	7.6

EVA project

Photos of EVA survey wells April-May 2013

Photos by AFPRO or local participants
in the villages

Pimpalgaon Barav

PB1

PB2

PB3

PB4

PB5

PB6

Thote Pimpalgaon

TP1

TP2

TP3

TP4

TP5

TP6

Palaskheda Pimple

PP1

PP2

PP3

PP4

PP5

PP6

Asarkheda

A1

A2

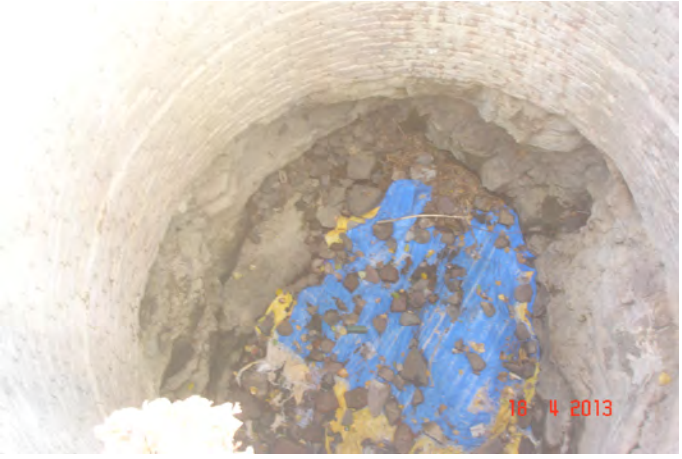
A3

A4

A5

A6

Dongaon



D1

D2

D3

D4

D5

D6

Niwdunga

N1

N2

N3

N4

N5

N6

Malegaon

M1

M2

M3

M4

M5

M6

Warudi

W1

W2

W3

W4

W5

W6

Kadegaon

K1

K2

K3

K4

K5

K6

About the Project

The EVA project focuses on the state of Maharashtra. More than 30 % of the state of Maharashtra falls under the rain shadow area and about 84 % of the total cultivated area is rainfed. Drylands in Maharashtra face the combined stress of human pressures and drought. Communities within these drylands are poor and face extreme conditions of water stress. This pilot project aims to assess the extreme risks and vulnerabilities to climatic extreme events in the drylands of Maharashtra and their impacts on agriculture and water resources, and the implications for community-based adaptation in response to these extreme events.

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Environment Department
Government of Maharashtra