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Trials on Hydro Meteorological Analysis for Spate Irrigation Development in Oromia, Ethiopia

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Abstract: The current report discusses issues of the spate irrigation project executed in the Oromia Regional state of Ethiopia in collaboration with Japan International Cooperation Agency (JICA) and Tokyo University of Agriculture (TUA), particularly addressing to necessity of watershed analysis in Boro Dodota. Spate irrigation is newly introduced in the region in modern and scientific approach since 2004, and many challenges are observed in planning, design, and management of the system. Among these challenges estimation of amount and period of occurrence of spate flood is principal. The project is located at altitude of 1,500 m that can be categorized as lowland area with frequent crop failure due to erratic rainfall and high evaporations prevailing. Automatic hydrological and meteorological observation systems with short data logging interval have been established in the divide line of Boro Dodota stream since March 2008, and data from these stations will be analyzed using GIS and compared with the actual conditions of the project. The result of the analysis will be used in water management of this scheme, and useful recommendations for other similar schemes will be forwarded.

Keywords: Hydro-meteorological data, Land use, Semi-arid region, Spate irrigation, Watershed

1. Introduction

The spate irrigation is a unique water management system in arid and semi-arid region which collects flush flood of ephemeral/intermittent streams originating from highland areas and distributes to areas of little and uneven rainfall (i. e. low land areas) resulting in increased soil moisture. The State of Oromia in Ethiopia is approximately 36 million ha accounting for almost 32% of the country, and consists of three agro-ecological zones, namely: 'high lands' with an altitude above 2,000 m, 'mid-altitude lands' with altitudes ranging from 1,500 to 2,000 m, and 'lowlands' with altitudes below 1,500 m. The lowlands are characterized by few and erratic distribution of rainfall resulting in difficulty to sustain the crop production. The food insecurity problem is even worst in lowland areas, which cover about 30% of the total land area of Oromia. Therefore, traditional spate irrigation had been practiced using simple diversions made from stone, wood, or sand in those dry lands of the country. Since 2004, the State of Oromia has implemented to advance the spate irrigation with modern and scientific approaches. The Boro Dodota spate irrigation project is the first case of the modern spate irrigation in the State having 5,000 ha of command area, where there is frequent crop failure due to the erratic rainfall condition. The current report discusses contexts, constraint, and prospects of the project, particularly addressing to necessity of watershed analysis.

2. Material and Method

The Boro Dodota spate irrigation project is located at 8˚11' N and 39˚22' E. The area is at boundary of tropical humid climate. The average altitude of irrigable area is 1,500 m. The slope of the area ranges from 1 to 5%. The mother material of the soil in the area is volcanic ejecta (mainly ash cinders and pumice) with light brown and gray colors. The soil has low strength hence easily disturbed and eroded by wind and water. Further, the soil in the area has high infiltration and rapid drainage. Dominant rain fed crops over the area are wheat, barley, maize, teff and haricot bean (80% is cereals) with yield ranging from 4 to 10 quintals per hectare, which is very low yield due to limited rain compared to the potential evaporation (see below). The main target of the project is to undertake supplementary irrigation during the rainy season from June to September.

The Boro River is characterized by intermittent stream located under the Chilalo Mountains with 4,000 m asl. The project plan is to establish a diversion structure at the Boro River at 1,840 m in altitude

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and 66.5 km below the extreme upstream source of the river, and to design the intake floods maximum up to 6 m^3/s into 5,000 ha of command area. Mean annual rainfall in the command and the catchment areas are 804 and 1,298 mm, respectively. Mean annual pan evaporation is 1,600 mm. The catchment area of Boro River is 50 km^2 and its shape is elongated slender. Based on visual observation and estimation during project study, the land use cover of the watershed was found that 20% is high land bushes and scattered trees, 70% is cultivated land, and 10 %is grazing lands.

Discharge analysis of Boro River was conducted according to flood trace, farmer's empirical knowledge, and visual observations. One automatic meteorological observation system was established in March 2008 in the command area (HOBO Weather station, Onset Computer Co., Bourne, MA, USA) (**Fig. 1**). The system records rainfall data with 10 minutes intervals. From the rainfall data observed, intensity of rainfall can be determined to use for catchment analysis and computation of peak flood which is expected at the head structure. It is quite true that long year data is necessary to come up with good results and recommendations but the data obtained from the stations established can be used as an indicator.

In order to evaluate the physical discharges of the river, pressure gauges (HOBO U20-001, Onset Computer Co., Bourne, MA, USA) were installed on Boro stream (since September 2008) and at intake point of headwork (since July 2008) (**Fig. 2**, **Fig. 3**). The pressure gauges record the absolute pressure in the water and the atmospheric pressure at the same point with an interval of 20 minutes. A hydrostatic pressure is derived from the absolute pressure in the water and the atmospheric pressure, namely; the difference in the two measurements is equivalent to the water level. Due to delay of installation of the pressure gauges on Boro stream, only the water level monitored at the intake point of the headwork was used for the evaluation in this report.

3. Results and Discussion

According to the discharge analysis, mean flow in each month from June to September were estimated to be 7, 12, 15, and 7 m^3/s, respectively (**Table 1**), while the peak flow from flood marks estimated to be 100 m^3/s. However, the amount of intake flow was insufficient to moisten the cropping fields at the end of the command area. This is in part due to under estimation of the discharge analysis derived from the flood trace. The result indicates the importance and necessity of a physical hydrological observation of the watershed. Therefore, it is indispensable to install multipoint hydro-meteorological observation systems having short data logging intervals (less than an hour) in the watershed.

As shown in **Figure 4**, the command area had 436 mm of rainfall in the rainy season of 2008. Usually, daily rainfall was less than 20 mm with exceptional event over 40 mm (the end of July). Although the water level record in June was not detected due to delay of installation of the

Fig. 1. Automatic meteorological observation system in the command area.

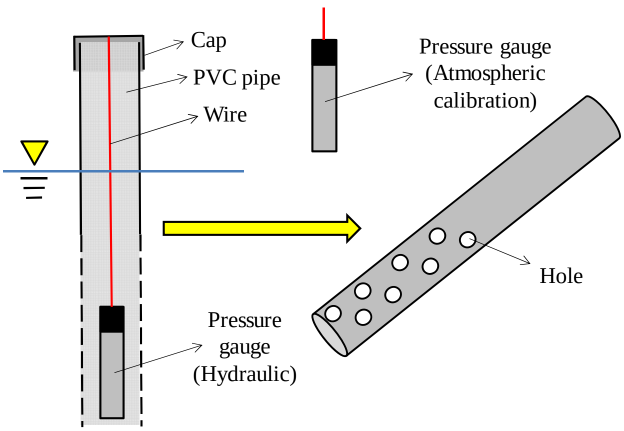

Fig. 2. Schematic diagram of a pressure gauge.

Fig. 3. Pressure gauge installed at intake point.

Table 1 Monthly spate flow as transferred from the flood marks.

Months	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Discharge (m^3/s)	0	0	6	8	1	7	12	15	7	2	0	0	**5**

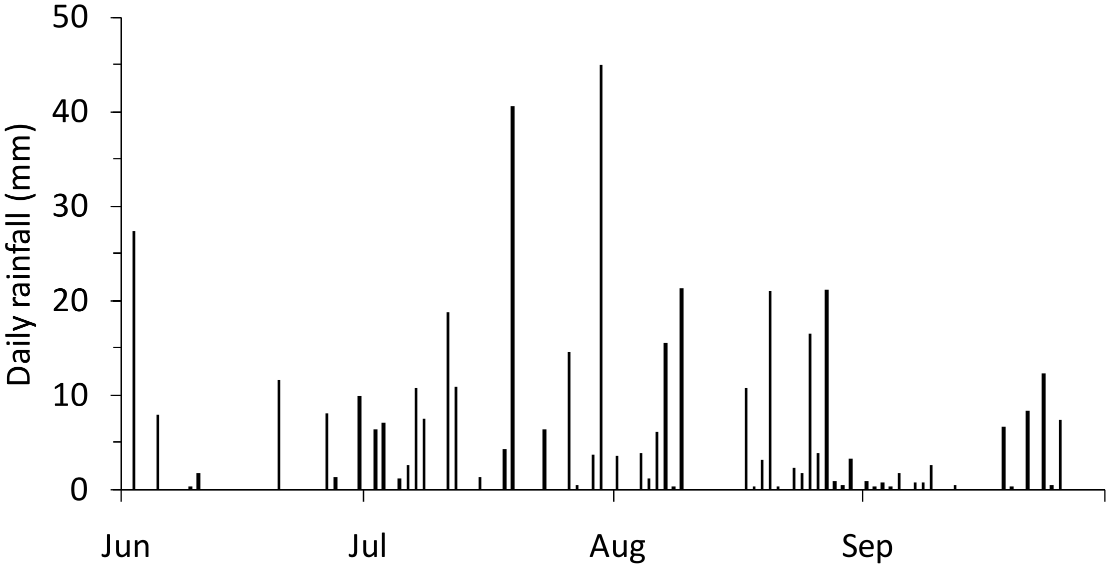

Fig. 4. Rainfall record from June to September, 2008.

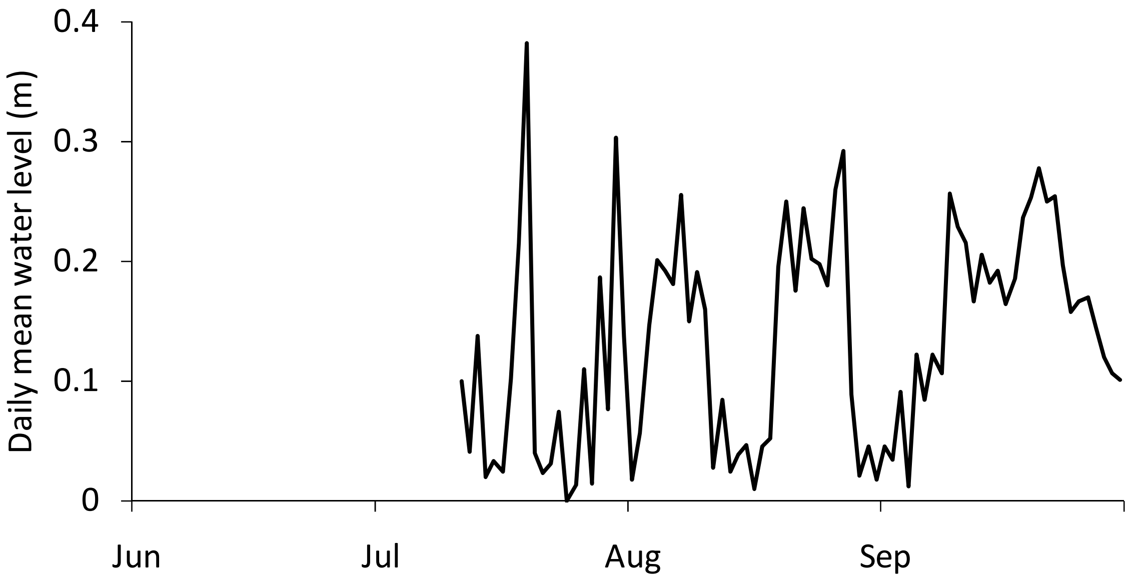

Fig. 5. Water level record derived from pressure gauge in June, 2008.

pressure gauges, the water level of intake flow was ranging from 0 to 0.4 m with an average of 0.13 m overall (**Fig. 5**). Actually, the location of water level observation was several km away from the point where the rainfall monitoring was undertaken, changes in the water level was linked with the rainfall record (Figs. 4 and 3). The authors will undertake topographic survey of the Boro river in near future. The water level record will be analyzed to obtain the amount of discharge by combining with the result of the topographic survey.

Considering those challenges, the following attempts must be made, namely; a precise survey of the command area using the Ground Positioning System (GPS) and watershed analysis using Geographic Information System (GIS). The attempts will be also made to extent meteorological (i.e. rain) and hydrological (i.e. discharge) monitoring systems as well as collecting land use data over the catchment area of the Boro river. Out of the divide line of the Boro catchment, there are several meteorological stations, for example, the Asella Meteorological station which is at 30 km air distance and 2,420 m alt. and the Wonji Meteorological station which is 28 km air distance and 1,545m alt (**Fig. 6**). The meteorological data recorded at those stations are also able to be set in the GIS analysis to determine discharge of the Boro river and the water demand of the command area.

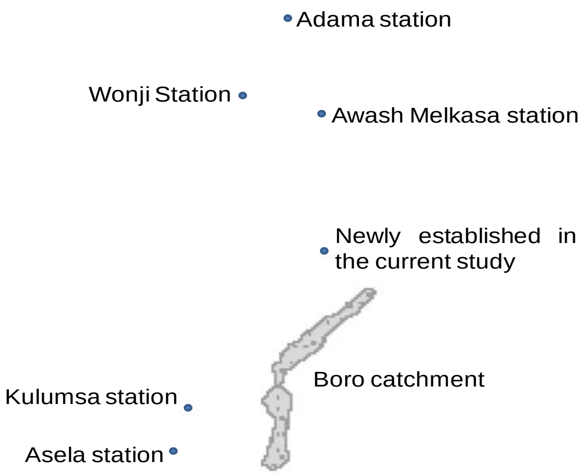

Fig. 6. Location of meteorological stations and catchment.

4. Conclusions

After obtaining necessary data from the automatic observation systems, and based on the result of the observations and analyses, recommendations useful for estimation of amount and period of flood suitable for diversion and distribution will be made. The results will be used as an input for water management, particularly supply and distribution of water on the Boro Dodota spate irrigation scheme and other similar schemes. Wide area analysis tools such as GIS have high potential for the watershed analysis in the semi-arid regions with limited scientific information such as the central Ethiopia. The current project of the spate irrigation development will be one of valuable case study for wise use of water resources in the semi-arid region.