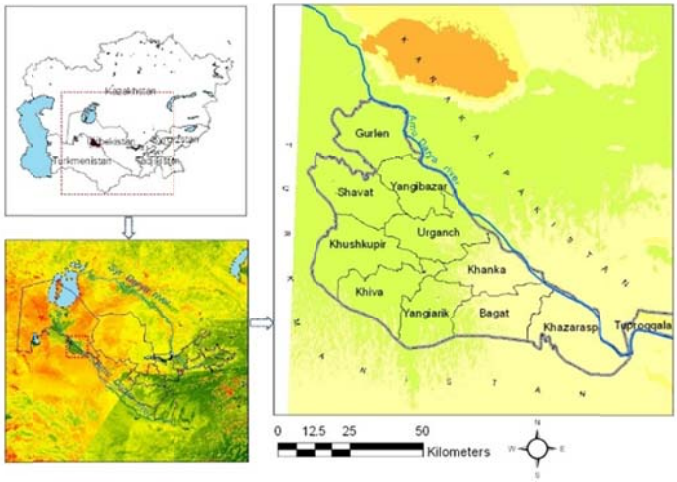
GIS BASE SIMILARITY MAP FOR UP-SCALING IRRIGATION SCHEDULING

Introduction

Due to environment and agricultural system in Khorezm, located between 41^0-42^0 N, 60^0-61^0 E (Fig.1), high evapotranspiration (ET) of 1378 mm $year^{-1}$ (Christopher et. al, 2102) vastly outpaces given water in agriculture, irrigation amount of 1100-1200 mm $year^{-1}$ with preseason salt leaching of 500-600 mm $year^{-1}$, seepage throughout extensive 1866.8 km unlined irrigation networks. Mismanagement of land and water resources under Soviet rule to fulfill production plans while neglecting environmental impacts, led to decline soils productivity across the irrigated areas of Central Asia. To manage ground water and salt balance, 3718.1 km inter-farm, 2921.8 intra-farm collector-drainage network had been developed. Khorezm region hosts 275 000 ha irrigated lands and most of the area moderately and highly saline. Existing soil data sets of Khorezm region indicates silt loams (55%) and together with sandy loam (12%) and loams (13%) they constitute 80 % of all soil layers (Akramkhanov et al., 2012).

Figure 1. Geographic location of the Khorezm region



Since region's economy heavily relies on agriculture, both present and future inefficient water usage and impact of climate change are potentially anticipated under the condition of limited natural resources in the region (Farkutsa, 2006, Tischbein et

al., 2012, Ibrakhimov et al., 2007). Recent research findings had indicated vast of water for leaching and irrigation without accounting soil water content and crop water demand, and climate conditions (Akramkhanov et al., 2012), causes waterlogging and secondary salinization (Tischbein et al., 2013). Improper leveling of crop fields require additional water and cause heterogeneously distribution of water through the field, which can reduce crop yields (Egamberdiev et al., 2008). ET based irrigation scheduling taking into consideration of groundwater (GW) and soil hydraulic properties (SHP) favors to improve optimal usage of water. The main goal of this section is to up-scale amount and timing of irrigation at the irrigated areas where similar condition of soil and ground water exist, exploring geographic information system (GIS) base techniques.

Materials and methods

Existing soil data sets of Khorezm region, all together 1,884 had a complete set of point base information, indicate silt loams (55%) and together with sandy loam (12%) and loams (13%) they constitute 80 % of all soil layers (Akramkhanov et al., 2012). The main dominant crops in the region are cotton (Gossypium hirsutum L.), winter wheat (Triticum aestivum L.) and rice (Oryza sativa L.) are irrigated using furrow- or flood-based irrigation methods (Farkutsa, 2006). Based on guidelines of water-application which was developed in the 1970s, the seasonal irrigation amounts 450–640 mm for cotton, 350 mm for wheat and 2620 mm for rice.

The national agency of Hydrogeological Melioration Expedition (HGME) had been established long-term observations on GW table. The HGME conducts measurements from more than 2000 monitoring wells (Ibragimov et al., 2011) with installation depth of 3–3.5 m. HGME measures GW table every 5 days interval during the irrigation and leaching period (from March to August).

To delineate GW table depth a Thiessen polygon is used in the environment of GIS for the representation of a GW sub-surface distribution (Coxwin et al., 1996; Magesh et al., 2012). Each Thiessen polygon contains only a single point input feature. Any location within a Thiessen polygon is closer to its associated point than to any other point input feature. Soil texture and spatial distribution of long term average GW maps (time series maps in ten daily interval from June 6 to September 10, 2015) combined into a layer stacked information taking into consideration various water years (high, medium and low). These data then converted into a crop field using zonal statistics in GIS spatial analysis tools.

In addition, in order to determine impact of GW contribution into crop ET, an experiment was conducted at individual crop field in Khushnudbek farm, located between 41.35^0 N, 60.54^0 E within the "Astana" water consuming association (WCA), Yangiarik district of Khorezm region. The field is cultivated by cotton that has typical soil type of loamy texture. Soil moisture were measured using automatic device within soil horizons (0-30, 30-60, 60-90 and 90-120 cm) for growing period (from June 6 to September 10) throughout irrigation period of cotton. Volumetric soil moisture sensors ThetaProbe type ML2x (Delta-T Devices Ltd., UK). It was inserted vertically to obtain topsoil moisture content and horizontally along a 30 cm deep trench to obtain average readings for the soil moisture of the layer. In total 4 readings were made per location and their average value was used for the analyses. Since GW table play crucial role for scheduling of irrigation, 9 monitoring wells were installed in the area. The GW table were measured manually in a 10-daily interval and one of them which is close to soil moisture device pf meter, is equipped with automatic depth measuring sensor (diver). To estimate potential evapotranspiration (ET_o) according to Allen et al. (1998), FAO developed ET calculator was used, applying field measured climate parameters. The mini climate station (HOBO) was installed with 4 instruments (Temp, Rel. hum, Wind speed and direction) at 41.349 N, 60.538E geographical location. Soil moisture, GW fluctuations and reference ET_o data in a 5-

10 daily interval were used as input data into UPFLOW model to estimate capillary up-flow (Cg) of GW from shallow table that contribute capillary rise GW for crop rooting zone (Raes D., 2009) under specific environmental conditions. Based on crop coefficient (K_c) were taken from Table 17 of the FAO 56 (Allen et al., 1989)., Cg and ET_o, irrigation scheduling was estimated for cotton. In order to estimate similarity map of vast areas within the Khorzm region, soil texture and long term average GW table condition were identified using multi-temporal spatial analysis tools with the help of GIS techniques.

Results and discussion

In order to compute amount of water that moves upward to soil profiles from a shallow water table for evapotranspiration (ET_o) UPFLOW was conducted to estimate at the specified environmental conditions of cotton field. Results of UPFLOW model yielded in total of 200 mm of water that may contribute water supply into the cotton root zone within loamy soil type. Weather data measured beyond the field station is combined with other data measured in the Urgench station near the Urgench city (20 km far from research area) used to fill gaps, showed ET_o and ET_a of 514 and 515 mm, respectively during irrigation period from June to September, which is almost equal. According to resulting data, ET base irrigation scheduling computed according to soil types. Results showed that 410 mm water is required by cotton at the condition under medium loamy soil and 610 mm in heavy loamy soil, that account temporal dynamics of GW and ET_o (table 1).

Similarity map of crop area according to selected criteria (e.g., soil texture with loamy soil) yielded 54 000 ha, whereas the area with similar GW condition during the growing period - 63 000 ha, in combination of both constitute 20 and 24 % of total irrigated area, respectively (fig. 2).

Conclusion

Evapotranspiration (ET) base irrigation scheduling can lead to optimum irrigation water use based on a simple water balance concept particularly in arid regions. Long term climate data sets measured in dry areas are available and under the site specific characteristics and desired irrigation needs. Scheduling irrigation favors to use water and land resources efficient and effective.

Table 1.

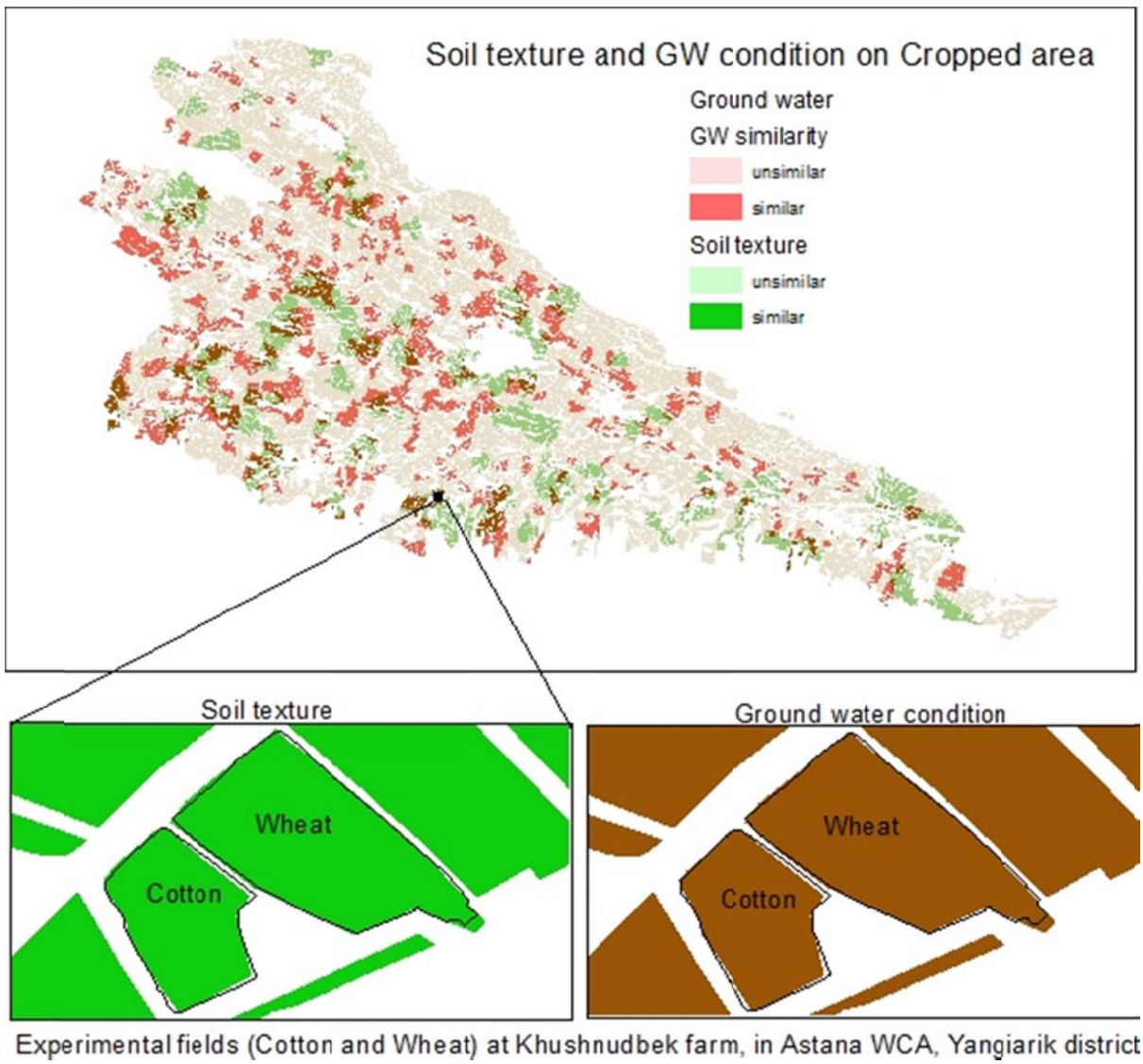
		Irrigation schedule of Cotton in 10 days period																		
№		April			May			June			July			August			September			
1		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	м3/га
2	Root zone	0.1	0.15	0.2	0.25	0.3	0.3	0.35	0.4	0.45	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	
3	Kc	0.35	0.35	0.35	0.35	0.35	0.35	0.4	0.5	0.6	0.8	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.0	
4	Etp	31.1	36.1	37.6	43.100	45.900	55.4	54	59	56.4	54.400	53.4	54	49.3	47.5	45.1	38.4			
5	Ete	10.9	12.6	13.2	15.1	16.1	19.4	21.6	29.5	33.8	43.5	53.4	64.8	59.2	57.0	54.1	46.1			
6	Cf							14	12	12	13	20	27	29	18	27	22			
	gw							1.78	1.88	1.90	1.87	1.67	1.52	1.39	1.36	1.45	1.66			
7	Total Ete							108												
8	Irrigation norm	**Medium loam 1000/230**						**69**		**91**		**111**		**143**						**4130**
9		**Light loam 1000/200**						**58**		**77**		**93**		**122**		**118**				**4680**
10		**Heavy loam 1000/270**						**81**		**122**		**142**		**160**		**162**				**6660**

The irrigation norm, amount and time of irrigation keeping soil moisture at 50 % FC, was computed using following equation;

$I_n=R_z*F_c\ h/^{-1}-C_g$

where I_n is irrigation norm, R_z is root zone of soil profile, $F_c\ h/^{-1}$ is field capacity of one meter soil horizon and C_g is sum of capillary upward flow from shallow ground water in mm/day^{-10}.

Figure 2.



Experimental fields (Cotton and Wheat) at Khushnudbek farm, in Astana WCA, Yangiarik district

Similarity of crop area where soil texture is loamy which is fixed with experimental field is given green color and similar condition of GW dynamics at growing period is given red color and where the brown color contrasts best fits of soil texture and GW condition at the same locations.

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