Hydrol. Earth Syst. Sci. Discuss.,
doi:10.5194/hess-2016-155-AC3, 2016

Hydrology and Earth System Sciences
Discussions
Open Access

HESSD

Interactive comment

Interactive comment on "Is groundwater sufficient to support sustainable irrigation agriculture in a reclaimed wetland region?" *by* Z. Pang et al.

Z. Pang et al.

z.pang@mail.iggcas.ac.cn

Received and published: 26 August 2016

Thank you for your comments concerning our manuscript entitled "Is groundwater sufficient to support sustainable irrigation agriculture in a reclaimed wetland region?" (MS No.: hess-2016-155). Those comments are valuable and helpful for improving our manuscript. We have numbered the comments for clarity. Responses are described one by one as follows:

Comment 1: a) the research question is very unspecific, i.e. there is no clear hypothesis which allows the reader to understand the underlying plan of the study-design.

Reply 1: In this study, we tried to figure out whether groundwater is sufficient to support sustainable irrigation agriculture in terms of water quantity and quality. We tried to answer the question from the perspectives of groundwater residence times, recharge

Printer-friendly version

Discussion paper

mechanisms, interactions with surface water and groundwater regime with evidences from hydrogeochemical and isotopic tracers. Following the first sampling program in 2009, we wanted to explore whether the groundwater systems behave differently with different hydrogeological settings, then the second sampling program for hydrogeochemistry and isotopes was conducted in 2011 along the transect A-A' across different hydrogeological settings. Finally, the hydrogeochemical and isotopic tracers data was analyzed and discussed to answer the question. From the perspective of stable water isotopes, isotopic compositions of groundwater in the unconfined area are more enriched than that of groundwater in the confined area and some groundwater samples in the unconfined area is located on the local evaporation line (Fig. 7 and Fig. 8), indicating the links of the unconfined groundwater with the surface water. From the perspective of hydrochemistry, high NO3- and Ca2+ concentrations can be found in the shallow groundwater in the unconfined area (Districts I and III), indicating the interactions with irrigation water, while those in the confined area are generally low. From the perspective of 3H values, groundwater in the unconfined area shows a wide range of 3H values. Especially those groundwater samples near the river have high levels of 3H (6.5-71.3TU) indicating the links with river water. In a word, the groundwater in the unconfined area have strong links with the surface water, while groundwater in the confined area largely recharged by lateral flow. We found that hydrogeological conditions are the main controlling factors. In District I and III of the study area, the aquifers are composed of highly permeable cobble and gravel deposits and unconfined. In contrast, in the eastern part (District II), the aquifer is covered by a 16-20m thick clay layer and confined or semi-confined. The low 3H values in the confined area indicate that the groundwater is pre-modern and high 14C ages show that the recharge rate is very low. Based on the continuous decline of groundwater table, the groundwater alone is not sufficient to support sustainable irrigation agriculture. In the unconfined area, while the groundwater has strong links with surface water and relatively high recharge rate with stable groundwater table, the water quality is deteriorating affected by surface water which is unsustainable for irrigation agriculture. Furthermore, some samples with high

Printer-friendly version

Discussion paper

NO3- and Ca2+ concentrations (especially NO3-) in the confined area may indicate the leakage from the shallow unconfined groundwater. If the pumping in the confined area continues at or increases from the present levels, the groundwater table declining will continue and the water quality will also deteriorate in the future, which is also indeed unsustainable.

Comment 2: the question stated in the manuscript title is not answered in a quantitative way by the analysis presented in the paper.

Reply 2: It is our conclusion that groundwater is insufficient to support irrigation agriculture, an answer to the question raised in the title of the paper. This answer has been supported by scientific evidences including groundwater residence time, recharge mechanisms and the interaction between groundwater and surface water in areas with different hydrogeological conditions, typically for a reclaimed wetlands.

Comment 3: Introduction The introduction section misses a brief introduction on the previous knowledge about the interplay between irrigation practices and recharge mechanisms for confined and unconfined aquifers with a clear statement of the research gaps which will be closed by this paper.

Reply 3: You are right. This can be further explained and literature cited. It is especially interesting to note that, groundwater is a vital source of drinking water and irrigation water in north China, especially in areas of former wetlands, such as Sanjiang Plain, the study area of this paper, people believe that groundwater is sufficient. However, problems have occurred in north China plain, an area with irrigation agriculture. Many shallow unconfined aquifers in north China have been contaminated by nitrate and other pollutants with recharge from surface water due to agricultural activities (Chen et al., Journal of Hydrology, 326, 367–378, 2006; Zhu et al., Hydrogeology Journal, 16, 167–182, 2008). Consequently, more and more deep confined groundwater has been used for irrigation agriculture and drinking water. The deep confined groundwater may not be replenished by modern recharge and the recharge rate is low (Edmunds et al., 2006). Continuous exploitation of confined groundwater may cause water table decline and there is also the potential for deep groundwater that is not fully confined to be contaminated by downward leakage from overlying shallow groundwater. In this study, we apply a multi-tracer approach to demonstrate that groundwater may not get appropriate recharge so it is not sustainable to use it as a sole source. Environmental tracers have been demonstrated as useful tools in understanding groundwater residence times, recharge mechanisms and the interactions between groundwater and surface water in a wetland terrain with diverse hydrogeological settings.

Comment 4: Study Area While the results and the discussion are presented with respect to particular sampling locations there is no spatial information on the locations of these sampling locations (I have seen the coordinates in the tables, but this doesn't help/ would take a lot of time to locate the different stations on the map).

Reply 4: On the one hand, we focus on understanding of differences of groundwater residence times, recharge mechanisms and the interactions between groundwater and surface water in different districts with diverse hydrogeological settings rather than some locally particular locations based on the tracers' data to answer the research question in this study. On the other hand, the locations of samples taken at three farms of HH, QF and QS which were used for comparative analysis are presented schematically in Fig. 1.

Comment 5: Methods There is no clear methodology/procedure which explains how the results of the chemical analysis are treated. This also marks the big lack in this paper: There is no quantitative analysis of observed concentrations. For example, the presented nitrate and calcium concentrations are only "analyzed" with a rather surficial interpretation of "concentration groups" which does not fit at all (see comments on the result section). The method section would need a clear concept how the results of the chemical analysis were sorted, ranked, correlated, . . . and a hypothesis how this procedure will lead to the answers sought by this paper.

Reply 5: The answer to our problem in this study is more dependent on isotopic data. The hydrochemical data are combined with isotopic data to determine whether vertical recharge from surface water is occurring and to describe the water quality issues. Due to the lack of natural nitrate in most geologic formations, high nitrate concentrations generally indicate contamination by fertilizers from agricultural activities. The hydrochemical concentrations in different areas were used to determine where the interactions between groundwater and surface water and vertical recharge are occurring. Our chemical data may serve as baseline for future studies, especially on the water quality changes. See also "Reply 6" as follows.

Comment 6: While the results of the isotopic analysis show the overlay of surface and groundwaters the interpretation of the major ion concentrations does not fit at all: Figures 3 and 4 show similar concentrations for Districts II and III either for nitrate and for calcium and not as presented for District I and III. Consequently, the following interpretations should be reassessed.

Reply 6: Isotopic compositions of groundwater in the unconfined area (Districts I and III) are more enriched than that of groundwater in the confined area (District II) (Fig. 7). Most of the groundwater samples in the confined aquifers are plotted on the LMWL, while some groundwater in the unconfined aquifers are on the local evaporation line, indicating groundwater in the unconfined aquifers is more easily recharged by evaporated surface water with more enriched isotopic compositions. The groundwater samples at HH and QF farms (District II) (Fig. 8) are more depleted in heavy isotopes than the surface water, further indicating that lateral groundwater flow from mountainous area dominates the groundwater recharge, and that interactions with surface water barely occur. Groundwater at QS farm (District III) shows a wide range of tritium levels (<1.0-71.3TU), corresponding to the different sampling locations. Samples with high levels of tritium (6.5-71.3TU) are from shallow groundwater collected near the river, indicating strong links with river water. In District I, with strong links with surface water, groundwater nitrate concentrations can reach 458mg/L, while in the confined aquifer (District

II) with weak links with surface water, nitrate in most of the samples is less than 10mg/L (Fig. 3). The distribution of groundwater Ca2+ behaves similarly to groundwater nitrate (Fig. 4). The high Ca2+ values are derived from the soil layer with high Ca2+ contents by leakage of surface water in District I. Some samples with high NO3- and Ca2+ concentrations in the confined aquifer may indicate leakage from the shallow unconfined groundwater as groundwater table is continuously declining. The low NO3- concentrations in District III may be attributed to less fertilizers used in District III than in District I and "wetlands function" as discussed in section 5.3.

Comment 7: The Deuterium enrichment in the paddy field water samples is interpreted as condensation (Figure 6). This is wrong, condensation fractionates along the LMWL (saturated conditions). A possible reason might be methanogenesis which can cause heavy Deuterium-enrichment of soil water.

Reply 7: The water formed by condensation of evaporated moisture will also locate above the LMWL (Pang et al., Processes affecting isotopes in precipitation of an arid region, Tellus B, 2011, 63(3): 352-359.). We agree with you that methanogenesis may also be the reason which can cause heavy Deuterium-enrichment of soil water (Chidthaisong et al., 2002, Geochimica et Cosmochimica Acta, 66(6), 983-995.).

Comment 8: The discussion section misses for the largest parts the reflection of the actual literature with the results and the determination how the results presented within this study contribute to our understanding of the governing processes. For example, there is no explanation how the results of the groundwater age dating correspond to the various major ion concentrations (e.g. nitrate) for the different aquifer types and which recharge processes could cause observable chemical groundwater compositions.

Reply 8: The 2H and 18O isotopic compositions and 3H values in the unconfined area indicate that groundwater has strong interactions with surface water and modern recharge occurred, while groundwater in the confined area is recharged dominantly by lateral flow from the mountains around (discussed in Reply 6). So the groundwater age in the confined area is generally older than that in the unconfined area. The vertical infiltration recharge from surface water with high nitrate from agricultural activities resulted in the generally high nitrate concentration in the unconfined area. However, it is not yet a serious problem in this area so should not be over emphasized, just to keep our argument well-ballanced.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-155, 2016.