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Modelling the impact of nutrient recycling on groundwater resource quantity and quality in an irrigated semi-arid tropical catchment

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Agriculture is increasingly relying on groundwater irrigation. In the context of climate change, it is crucial to develop reliable methods for sustainability assessment of current and alternative agricultural systems. Among agricultural-borne non-point source pollutants, nitrogen has been the focus of many studies due to its ubiquitous impact on ecosystems, sometimes referred as the “Nitrogen cascade”. Modelling such impacts is of primary importance for understanding current agrosystems and to be able to assess their evolution.
In the Berambadi catchment (84km2, Karnataka, Southern India), which is part of BVET/ Kabini Critical Zone Observatory, we monitored the effect of application of fertilizers and over-exploitation of water resources by intensive tube well irrigation on groundwater resource. The monitoring highlighted a huge spatial variability of groundwater composition with Cl and NO_3 contents spanning 3 orders of magnitude with the highest concentrations found in the most severely groundwater depleted areas. The high nitrate contents in groundwater (on average 100 mgNO_3/L, up to 360 mgNO_3/L) induces a “hidden” supply by irrigation of 50 kg/ha/yr on average with extremes up to 200 kg/ha/yr (Buvaneshwari et al., 2017). Irrigation with this highly concentrated groundwater induces an important feedback in the soil-plant system. However, groundwater recycling is rarely taken into account in groundwater resource integrated assessment and modelling.
Monitoring of the soil pore-water composition was done for a common cash crop, Turmeric, in order to perform a nitrate balance at soil-plant scale and evaluate the influence of soil (Ferralsol vs Vertisol) properties on the flux of nitrate leached towards groundwater. A clear contrasted behaviour was found between the studied soils: the high permeability of Ferralsol induces a flush down of almost all the nitrogen input but limits the intensity of evapotranspiration and hence the risk of salinization. On the contrary, the low permeability and high holding capacity of Vertisols make water and nitrate consumption by the plants more efficient. Moreover, denitrification in the deep soil horizons may limit even more the nitrate output from Vertisol. However, chlorine (and other major elements such as Na, Ca, Mg) concentrations increased dramatically with soil depth, making Vertisol prone to salinization.
The water and nitrogen balances at the soil-plant scale were assessed by combining field data and STICS crop model for the two soils. To account for the significant feedback induced by the nitrate rich groundwater recycling, we further introduced the new nitrogen module in the developed integrated coupled crop and groundwater model (AICHA under the RECORD platform) which is designed to assess agricultural systems and their adaptation to climate change. The model results revealed that the solute recycling by pumping can lead to severe groundwater degradation both in terms of quality and quantity. Different scenarios were furthermore tested to optimize the fertilizer application to reduce nitrate leaching and to mitigate the high nitrate concentrations in groundwater.

Keywords: Groundwater quality; soil degradation; agriculture; integrated model