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Impact of intensified irrigated agriculture and climate change on nitrogen loading in the Amu Darya drainage basin, Central Asia

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Pollutant loading and water losses by evapotranspiration are two main problems of intensified irrigated agricultural in arid and semi-arid regions. Climatic changes can further increase water losses and alter transport pathways for contaminants and nutrients. Identification of dominant processes that control nitrogen (N) loading in the highly managed Amu Darya Drainage Basin (ADRB), the largest sub-basin in the Aral Sea Drainage Basin (ASDB), is considered by looking at a 40-years (1960-2000) data record of dissolved inorganic nitrogen (DIN). Furthermore, hydrologic distributed modelling was used to investigate how N transport pathways and travel times have changed with past irrigation expansion, and is likely to change further in response to projected future hydro-climatic trends. River discharge has decreased drastically during the considered 40-years period in ADRB. Future climate and land-use projections show that downstream regions even are at risk of total surface water depletion within a future 30-years period. Decreasing riverine DIN concentration was observed near the Aral Sea outlet despite increasing N fertilizer application throughout the 40-years period. The reduction in concentrations could not be explained by increased N crop uptake, improved fertilization application or improved irrigation efficiency. Instead, this must primarily be due to a considerable increase in reuse in irrigation which extends the flow-path lengths and enhances N retention. A relationship between increased recirculation ratio (defined as the basin-scale return flow divided by the outflow) and decreased Cout/Cin ratio was developed, and shown to be valid for a relatively wide uncertainty range. An observed six-fold decrease in DIN load was primarily, but not exclusively, due to the drastic river flow reduction. Consequently, N accumulation in the soil-groundwater system has accelerated since the N fertilization has been maintained high throughout the period of considerable decrease in N export from the catchment. Future climate change induced decreases in discharge would decrease the DIN loading even more both directly and by increasing the recirculation of irrigation water. In addition, the observed and projected diminished availability of surface waters imply that travel times are increasingly governed by the groundwater system. A change of main transport pathways from the irrigation-drainage systems to the groundwater system implies an increase of mean travel time from months to years in downstream regions. This can considerably enhance N retention, and affect N mass flows and their distribution in the catchment. Similar reductions in discharge as observed in the ADRB are projected for several arid and semi-arid regions around the world due to climate change and agricultural intensification, which could be associated with comparable shifts in N export and storage as shown for the ADRB.