**Abstract**

Developing rainfed-canola cropping in the paddy fields of the Northern Iran requires consolidating drainage systems in order to retrieve water logging conditions in these lands during rainy seasons. While second cropping is important in viewpoint of the optimal usage of green water resources for increasing national food security level and alleviating pressures on blue water resources, consolidating such systems may end up with environmental impacts. Such consequences may be intensified under global warming. Hence, in this research, the impacts of global warming on water and nitrate losses from a rainfed-canola cropping system under various artificial drainage systems was assessed using an integrated field-modeling approach. Field investigation was carried out in the 4.5-ha consolidated paddy fields of Sari Agricultural Sciences and Natural Resources University during two cropping cycles of 2015-2016 and 2016-2017. The drainage systems in this field included three regular subsurface drainage systems with different drain depths and spacings of, respectively, 0.9 m and 30 m ($D_{0.90}L_{30}$), 0.65 m and 30 m ($D_{0.65}L_{30}$), and 0.65 m and 15 m ($D_{0.65}L_{15}$), and a bilevel drainage system consisting of four drain lines with 15 m spacing and 0.65 and 0.9 m alternative depth (Bilevel). In addition to daily measuring drainage fluxes, nitrate concentrations in the collected drainage water were also measured every other weeks during the cropping cycles. The HYDRUS(2D/3D) model was applied to assess the consequences of climate change. This model was first calibrated and validated using data collected for all drainage systems during the selected cropping cycles, respectively, and then applied to simulate water/nitrate losses for different drainage systems under future climatic conditions. Future weather data were downscaled from 20 general circulation models and four RCP scenarios. The HYDRUS (2D/3D) model provided reliable description of soil water contents (*MBE*=-0.5% to 0.2%, *nRMSE*=0.005-0.034%, and *EF*=0.73-0.99), drainage fluxes (*MBE*= $-21.7\times10^{-3}$ to $24.9\times10^{-3}$ mm $d^{-1}$, *nRMSE*=0.23-0.37%, and *EF*=0.69-0.85), soil nitrate concentrations (*MBE*= -0.002 to 1.00 mg $cm^{-3}$, *nRMSE*=0.08-0.18%, and *EF*=0.51-0.88), and nitrate fluxes (*MBE*= -0.97 to 0.72 mg $cm^{-1}$ $d^{-1}$, *nRMSE*= 0.35-0.57%, and *EF*=0.77-0.87). The results of the field investigation showed that daily average drainage discharges under Bilevel, $D_{0.90}L_{30}$, $D_{0.65}L_{30}$, and $D_{0.65}L_{15}$ varied in the ranges of 0-231 $cm^3$ $s^{-1}$, 0-220 $cm^3$ $s^{-1}$, 0-227 $cm^3$ $s^{-1}$ and 0-250 $cm^3$ $s^{-1}$, respectively. Analyzing precipitation-drainage discharge correlations reveals that the precipitation intensity of 10 mm $d^{-1}$ is the threshold of drainage capacity reduction, and precipitation intensities beyond this threshold may result in water logging challenges in the study area. The modeling results indicate that climate change will cause an increase of up to 148% in average daily drainage fluxes and up to 125% in average daily nitrate fluxes compared to the base case. This will result in an increase of 4-125% in seasonal nitrate losses from various drainage systems, with the lowest and highest projections for the $D_{0.65}L_{15}$ and $D_{0.65}L_{30}$ systems, respectively. The HYDRUS-simulated results indicate that the $D_{0.65}L_{15}$ system is environmentally safer than the other evaluated drainage systems for predicted global warming conditions concerning water/nitrate losses. Based on the results, environmentally sustainable operations of these systems for expanding rainfed-cropping under climate change requires precious investigations when selecting drain depths and spacings

**Keyword**: the HYDRUS (2D/3D) model, RCP scenarios, climate change projections, drainage flux, nitrate loss, paddy fields.

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# Application of HYDRUS-2D model in analysis of climate change adaptation strategies to reduce nitrate losses in rapeseed cultivation from paddy fields equipped with underground drainage

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