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Quantifying Water-Energy-food Nexus based on CO2 emission in farm-land

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Water, energy, and food security in today's world have been hampered by high population and economic growth, pressures on limited resources, and climate change. Accordingly, balancing the various critical components of biomass in the form of a water-energy-food (WEF) Nexus approach is one of the essential pillars of water resources management, which will enhance the long-term sustainability of water resources by promoting sustainable development. Assessing the WEF Nexus based on CO_2 emissions leads to quantify the role of each component of WEF. This work aims to quantify WEF Nexus in a pilot study in the North West of Iran based on analyzing the CO_2 emission of the involved sectors. Gathering all require data that are involved in different activities in water, energy, and food sectors is the main challenge in this regard. Sahand Agro-Industry CO_2, established in 1996 and expanded in an area about 200 ha to produce alfalfa, maize, potato, rapeseed, sugar beet, and wheat. The area with an average annual temperature of 10.1 °C and bout 356 mm precipitation is located in a warm, dry-summer continental climate (Dsb climate, according to köppen climate classification). A detailed dataset including labor, machinery, diesel oil, fertilizer (nitrogen, potassium, and phosphorus), biocide (pesticide, fungicide, and herbicide), irrigation water (groundwater and surface water), and output per unit area per product has been collected for 2008-2017. We evaluated the WEF Nexus by estimating CO_2 emission based on the water and energy equivalent and food production per unit area of crop production systems. In this regard, we applied several indices, including the WEF Nexus, water, and energy consumption, mass, and economic productivity, to estimate the CO_2 emitted during a ten-year time period, besides the effect of changing the cropping pattern on the amount of CO_2 emission. Furthermore, we developed an approach to achieve optimal cropping pattern to minimize water and energy consumption and maximize productivity. Because of the detail calculation of mentioned indices and existing operational limitations, first, two margin scenarios were developed: 1- crop pattern with the lowest CO_2 emission and 2- Crop pattern with the maximum net benefit. For each pattern, we calculated the area for different crops. Then by combining these two marginal patterns and using dynamic programming, we developed 128 different patterns between the two mentioned margins. The results showed that as the differentiation in the amount of CO_2 equivalent for each crop, different cultivation patterns would have a different effect on the carbon dioxide emission. Water withdrawal (extraction, displacement, and distribution of water in the field) requires energy consumption, which varies depending on the source used for irrigation. Also, water productivity per kcal per m^3 will vary depending on the type of crop, cropping system, and agricultural management. Finally, we clustered scenarios based on CO^2 emission and net benefit and suggested the optimum condition.

Keywords: CO_2 emission, economic productivity, optimization, sustainable development, water-energy-food Nexus