Optimum Management of Water and Fertilizer for Potato in Soft rock and Sand Compound Soil Based on WHCNS Model: Scenario Prediction

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Abstract. Soil Water Heat Carbon and Nitrogen Simulator (WHCNS) model was used to simulate the soil water and fertilizer coupling effect of potato in soft rock and sand compound soil, with a view to establishing a scheme to optimize soil water and fertilizer in local climate and soil properties. In this study, excessive irrigation will directly lead to a significant increase in water leakage. When irrigation or relatively large rainfall occurs, the soil moisture leakage increases significantly. Especially when there is a coincidence between irrigation and rainfall periods, the corresponding water leakage increases even more drastically. For the water and fertilizer management of potato in the soil under the meteorological conditions in the study area, an irrigation system of no more than 119 mm and a fertilization system of no more than 121 kg N/hm² can be adopted. Excessive irrigation and fertilization cannot obtain more. Crop yields can only lead to increased water and fertilizer losses and reduced water and fertilizer use efficiency.

1. Introduction
The Mu Us sandy land located at the junction of Shaanxi, Mongolia and Ningxia provinces has a vast area, providing a great reserve of resources for replenishing cultivated land. How to manage the sand at a low cost and effectively is a major technical problem Han Yuchang [1-2] proposed the innovative ideas of compounding two kinds of materials into soil and further developing arable land through further research on the properties of soft rock and sand abundantly distributed in sandy land. With the support of the major project of land remediation in Shaanxi Province, a standardized and large scale project of soil and land reclamation has been innovatively implemented in Mu Us Sandland, greatly reducing the cost of land reclamation. Change soft rock and sand "two pests" as "a treasure", successfully achieved soft rock and sand scale, resource utilization [3-5]. Up to now, the use of the technology has accumulated a total of more than 100,000 acres of arable land in the region, mainly for potato and corn farming.

However, the development of arable land in sandy land is also facing the problem of water shortage and agricultural environmental pollution. Therefore, the rational development of water and fertilizer
management measures to achieve high crop yield, efficient use of resources and reduce the risk of agricultural environmental pollution purposes, to protect the national food and Resources and environmental safety has important practical significance. The traditional management measures of water and fertilizer through field experiments usually have the disadvantages of time-consuming and labor-intensive, high cost and so on. Due to the influence of meteorological, soil and field management measures in the study area, the results obtained have some limitations and one-sidedness, which greatly limits the popularization and application of the research results. The soil-crop system model based on field experiments can solve this problem well and has been widely used in crop production decision [6], water and fertilizer optimization management [7] and environmental impact assessment [8] application. Therefore, based on the planting experiment of potato, the main crop in the world, the paper used WHCNS model to quantitatively evaluate the nitrogen leaching, water-nitrogen balance and utilization efficiency of farmland with different sand and sand mixed with sand. To provide a scientific basis for water and fertilizer management measures of potato on newly added cultivated land in sandy land.

2. Materials and methods

2.1. Test Area Overview
The test sites are located in Daji Khan Village, Yuyang District (E109 ° 28'58" -109 ° 30'10", N38 ° 27'53" -38 ° 28'23"), Xiaijihan County, Yuyang District, Located in northern Shaanxi, elevation 1206-1215 m, the southern edge of the Mu Us desert. The area is a typical mid-temperate semi-arid continental monsoon climate zone, uneven temporal and spatial distribution of precipitation, adequate sunshine. The annual average temperature is 8.1 °C, the annual average rainfall is 413.9 mm, 60.9% of the rainfall is concentrated in 7-9 months, and the rain and heat are in the same period. The average annual sunshine hours is 2879 h, sunshine percentage of 65%. The total annual radiation is 145.2 kcal/cm². The main types of soil in the test site are mainly sandy soil, which nitrogen content of 0.75 g kg⁻¹, total phosphorus content of 0.63 g kg⁻¹, total potassium content of 26.51 g kg⁻¹, and organic matter content of 0.3 g kg⁻¹.

2.2. Experimental Design
Experimental design of the size of 15 × 12m of the district, set up two repeats, the district is divided equally into three 5 × 12m sub-district, respectively, consider the soft rock: sand 1: 1, 1: 2 and 1 : 5 and other three mixed ratio, each plot is only covered in the surface layer of 30 cm different mixed composite soil (soft rock crushed as much as possible to 4 cm in diameter to ensure that the surface of the sand and sand evenly mixed cover) The local sandy soil below 30 cm is generally homogeneous in the 30-160 cm soil profile due to the leveling of the land during land remediation. The main physical and chemical properties of three kinds of mixed soil and original sand are shown in Table 1.

| The mixing ratio: Soft rock: Sand | depth (cm) | Particle size composition (%) | Texture (American made) | Bulk density (g·cm⁻³) | total nitrogen (g·kg⁻¹) | total phosphorus (g·kg⁻¹) | total potassium (g·kg⁻¹) | organic matter (g·kg⁻¹) |
|----------------------------------|-----------|-------------------------------|-------------------------|----------------------|------------------------|-------------------------|------------------------|------------------------|
| 1:1                              | 0-30      | Grit 53.82    Powder 38.12  Cosmid 8.06 | sandy loam             | 1.37                  | 0.44                   | 0.50                    | 22.26                 | 2.26                   |
| 1:2                              | 0-30      | Grit 68.86    Powder 26.01  Cosmid 5.13 | sandy loam             | 1.52                  | 0.54                   | 0.55                    | 23.67                 | 2.61                   |
| 1:5                              | 0-30      | Grit 79.03    Powder 17.35  Cosmid 3.62 | sandy soil             | 1.56                  | 0.65                   | 0.59                    | 25.09                 | 2.97                   |
| Original sand                    | 30-160    | Grit 95.37    Powder 4.10   Cosmid 0.53 | Sand                   | 1.61                  | 0.75                   | 0.63                    | 26.51                 | 3.32                   |
The crop was planted as potato, which was planted on April 22, 2013. All the communities adopted the practices of irrigation and fertilization managed by local farmers. Before planting, the base fertilizer was applied in an amount of 120 kg N ha\(^{-1}\), and then rotary tillage machine was used to trowel 20 cm compound soil and fertilizer to the surface uniformly. A total of 5 irrigation times throughout the crop growing season, each time 55.6 mm. Topdressing twice with 69 kg N ha\(^{-1}\) applied.

2.3. Measurement items and methods
In the key growing period of several potatoes, soil samples of depth of 10, 20, 40, 60, 80, 100 and 120 cm were taken by soil drilling in test plots with different ratio of soft rock and sand, and the samples were fertilized and irrigated after a week. Soil samples taken immediately after the field into the refrigerator back to the laboratory for analysis, before the experiment with 2 mol / L KCl solution extraction (water to soil ratio of 5: 1), with an automatic intermittent chemical analyzer (cleverchem200) Determination of ammonium Nitrogen and nitrate nitrogen content, while drying method to measure soil moisture content. Soil moisture with neutron moisture meter (CNC100) determination, which once every two weeks to determine the depth and sampling depth. The dry weight and leaf area index of the crop were measured and the yield was measured at harvest. The basic meteorological elements (maximum temperature, minimum temperature, average temperature, rainfall, solar radiation, relative humidity, sunshine hours, wind speed, etc.) are provided by the Bureau of Meteorology in Yuyang District.

2.4. Introduction to the model
In this study, Soil Water Heat Carbon and Nitrogen Simulator (WHCNS) [9] was used to simulate the study. Based on the kinetic model of the combined transport of soil hydrothermal solutes, this model introduced the crop growth and development process, soil organic matter turnover, organic nitrogen mineralization and retention, urea hydrolysis, ammonia volatilization, nitrogen nitrification and denitrification And other processes, including meteorological modules, soil water, heat and nitrogen joint transport module, crop growth module, organic matter module, root absorption nitrogen, inorganic nitrogen module and field management module 7. It can be used to quantify most of the key processes in the soil-crop system.

The WHCNS model cites FAO’s meteorological module and the Dutch PS123 crop model, drawing on the theory of water solute transport associated with the Daisy, Hydrus-1D, RZWQM and LeachM models and modifying and refining it. This model, in days-steps, can be used to analyze soil hydrothermal dynamics, nitrogen anomalies, turnover of organic matter, crop growth and greenhouse gas emissions. The parameters are automatically optimized using the PEST (Model-Independent Parameter Estimation) automatic optimization tool. The WHCNS model is a systematic model for the quantitative analysis of the impact of field fertilizer and water management measures on crop production and the environment.

2.5. Model input
The parameters that the model needs to input include: (1) Basic information: latitude and altitude. (2)Soil information: thickness of soil layer, texture of each layer, pH, bulk density, organic matter, total nitrogen, hydraulic properties, solute transport parameters, C / N conversion parameters. (3) Field management information: irrigation time and quantity are non-time, method and quantity. (4) Soil initial conditions: water content, inorganic nitrogen. (5) meteorological data: daily solar radiation, the lowest temperature, the highest temperature, wind speed, humidity, rainfall, etc. (6) Crop parameters: crop growth optimum, maximum and minimum temperature, initial, middle and late crop coefficients, maximum and minimum graduation area, maximum assimilation rate, maximum rooting depth and so on.
3. Results and discussion

3.1. Water leakage and nitrogen leaching dynamic analysis

Figure 1 shows the dynamics of water leakage and nitrogen leaching at various ratios of soft rock to sand complex. Since the rainfall, the water leakage mainly occurred during this period, and the larger the rainfall, the larger the water leakage. As can be seen from the figure, excessive irrigation will directly lead to a significant increase in water leakage, when irrigation or relatively large rainfall occurs, soil water leakage significantly increased; especially when irrigation and rainfall period Coincidence, the corresponding Because of fertilizer goes with the water, the corresponding nitrogen leaching is closely related to the water leakage, and the nitrogen leaching also occurs primarily during the water leakage period. When the mixing ratio is 1: 5, the water leakage and nitrogen leaching in compound soil are obviously less than 1: 1, 1: 2. Some studies have pointed out that if peasants are accustomed to reduce the input of water and nitrogen by 30-60%, the loss of nitrogen leaching can be reduced by up to half [12-15]. Thus, for newly formulated compound soil, a more elaborate management system of water and fertilizer remains to be further studied in order to reduce water and nitrogen loss and improve water and nitrogen use efficiency as much as possible.

Fig 1. Dynamic of water drainage and nitrate leaching for 1:1 compound soil
3.2. Years of meteorological conditions analysis
Rainfall is an important influencing factor on crop irrigation volume. Crops water and fertilizer management under different weather conditions have different management methods. Therefore, it is necessary to simulate and analyze the coupling of water and fertilizer under different meteorological conditions on the basis of analyzing the multi-year rainfall in the study area.

Fig 2. The change of rainfall in Yuyang district Yulin city

Three meteorological conditions were studied separately through scenario simulations due to year representatives of the years of dry years, flat-water years and wet-years in 2005 (248.7 mm), 2009 (420.8 mm) and 2013 (567.4 mm) under the reasonable amount of irrigation and fertilizer. Irrigation volume were considered a total of 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700 and 750mm and other 15 irrigation treatment, the amount of fertilizer were considered 40, 80, 150, 120, 160, 200, 240, 280, 320, 360, 400, 440, 480, 520, 560 and 600 kg N hm⁻².

3.3. Scenario analysis
Through the simulation of water and fertilizer coupling, a total of 225 water-fertilizer coupling results for 2009 and 2013 are shown in Figure 3-5.

Fig 3. Analysis water and fertilizer coupling in 2005
Fig 4. Analysis water and fertilizer coupling in 2009

Fig 5. Analysis water and fertilizer coupling in 2013

As can be seen from the figure, for the years of dry years (2005), the amount of irrigation reached 245 mm and the amount of fertilization reached 120 kg N / hm², the yield could reach a more stable level. For Pingshui (2009), the amount of irrigation reached 119 mm and the amount of fertilization reached 120 kg N / hm², the yield could reach a more stable level. For the Fengshui year (2013), the amount of irrigation reached 104 mm and the amount of fertilization reached 121 kg N / hm², yield could reach a more stable level. According to the irrigation quotas of spring maize in the windy and sandy areas along the Great Wall in northern Shaanxi Province as stipulated in the "Water quota for industrial use in Shaanxi Province" promulgated by Shaanxi Provincial People's Government in 2004, the irrigation quotas of potato in the dry year, flat water year and wet years in the study area were: 270, 225 and 90 mm. In the year of water shortage, the amount of irrigation in Pingshui was less than the quota in "Industry water quota in Shaanxi Province". Therefore, from the scenario analysis of this study, for the management of water and fertilizer in mixed soil potatoes under meteorological conditions in the study area, an irrigation system of not more than 119 mm and a fertilization system of not more than 121 kg N / hm² can be adopted and too much The amount of irrigation and fertilizer can not get more crop yield, can only lead to increased water and fertilizer losses, water and fertilizer use efficiency decreased. Therefore, the coupling of limited irrigation water and fertilizer is an important way to save water, improve water use efficiency and strive for high yield of crops in arid and semi-arid areas. Under the condition of limited water resources, the key to dry land agricultural production is the rational cooperation of water and fertilizer.

4. Conclusion
Excessive irrigation volume will also directly lead to a significant increase in water leakage. When irrigation or relatively large rainfall occurs, the soil moisture leakage increases significantly;
especially when the irrigation and rainfall periods coincide, the corresponding water leakage it is a
sharp increase. For Xincheng compound soil, in order to reduce the loss of water and nitrogen as much
as possible and improve the efficiency of water and nitrogen use, a more detailed water and fertilizer
management system remains to be further studied. For the water and fertilizer management of potato
in the soil under the meteorological conditions in the study area, an irrigation system of no more than
119 mm and a fertilization system of no more than 121 kg N/hm² can be adopted. Excessive irrigation
and fertilization cannot obtain more. Crop yields can only lead to increased water and fertilizer losses
and reduced water and fertilizer use efficiency. Therefore, the coupling of limited irrigation water and
fertilizer is an important way to save water in arid and semi-arid areas, increase water use efficiency,
and strive for high crop yields. Under the condition of limited water resources, the key to agricultural
production in dry land is the reasonable cooperation of water and fertilizer.

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References
[1] Han J.C, XIE J.C, ZHANG Y. Potential Role of Soft Rock as a Natural Water Retaining Agent
in Mu Us Sandy Land, Northwest China [J]. Chinese Geographical Science. 2012, 22 (5):
550-555.
[2] HAN Chang-chang, LIU Yan-sui, LUO Lin-tao. Study on core technology of rapid composing
of soft rock and sand into clay in Mu Us sandy land. Chinese Journal of Land Science,
2012, 8: 87-94.
[3] Zhu D.W, Han J.C, Wang H.Y. The remediation method of sandy land in the feldspathic soft
rock area—a review, Carpathian Journal of Earth and Environmental Science. 2017, 12 (1):
49-60.
[4] WANG N, XIE JC, HAN JC A Sand Control and Development Model in Sandy Land Based on
Mixed Experiments of Arsenic Soft rock and Sand: A Case Study in Mu Us Sandy Land in
China. Chinese Geographical Science. 2013, 23 (6): 700-707.
[5] WANG N, XIE JC, HAN JC, Luo L.T. A comprehensive framework on land-water re
sources development in Mu Us Sandy Land. Land Use Policy. 2014, 40: 69-73.
[6] Williams J R, Jones C A, Dyke P T. A modeling approach to determining the relationship
between erosion and soil productivity [J]. Transactions of the ASAE, 1984 (1): 129-144.
[7] Hansen S, Jensen H E, Nielsen N E, et al. NP0-research, A10: DAISY: Soil Plant Atmosphere
System Model [M]. Copenhagen: The National Agency for Environmental Protection, 1990.
[8] Ahuja L R, Rojas K W, Hanson J D, et al. The Root Zone Water Quality Model [M]. Highlands
Ranch, Ohio: Water Resources Publications LLC, 2000.
[9] LIANG Hao, HU Kelin, LI Baoguo, et al. Coupling model establishment of hydrothermal C and
N processes in soil-crop-atmosphere system [J]. Journal of Agricultural Engineering, 2014,
30 (24): 54-66.
[10] Fang Q, Ma L, Yu Q, et al. Modeling nitrogen and water management effects in a Wheat-Maize
double-cropping system. Journal of Environmental Quality, 2008, 37: 2232-2242.
[11] Xing G X, 1998. N2O emission from cropland in China. Nutrient Cycling in Agroecosystems.
52: 249-254.
[12] Hu C S, Saseendran S A, Green T R., et al., Evaluating Nitrogen and Water Management in a
Double-Cropping System Using RZWQM. Vadose Zone J, 2006. 5: 493-505.
[13] Zhang X. Y, Pei D, Chen S. Y, et al. Performance of double-cropped Winter Wheat - Summer
Maize under minimum irrigation in the North China Plain. Agronomy Journal, 2006, 98:
1620-1626.
[14] Ju X.T, Xing G.X, Chen X.P, et al. Reducing environmental risk by improving N management
in intensive Chinese agricultural systems. Proceedings of the National Academy of Sciences
of USA, 2009, 106: 3041-3046.

[15] Zhu Z.L, and Chen D.L. Nitrogen fertilizer use in China-Contributions to food production, impacts on the environment and best management strategies. Nutr. Cycl. Agroecost, 2002, 63: 117-127.