A View of the Future in Groundwater Quality Testing of the Iranian Desert Plains

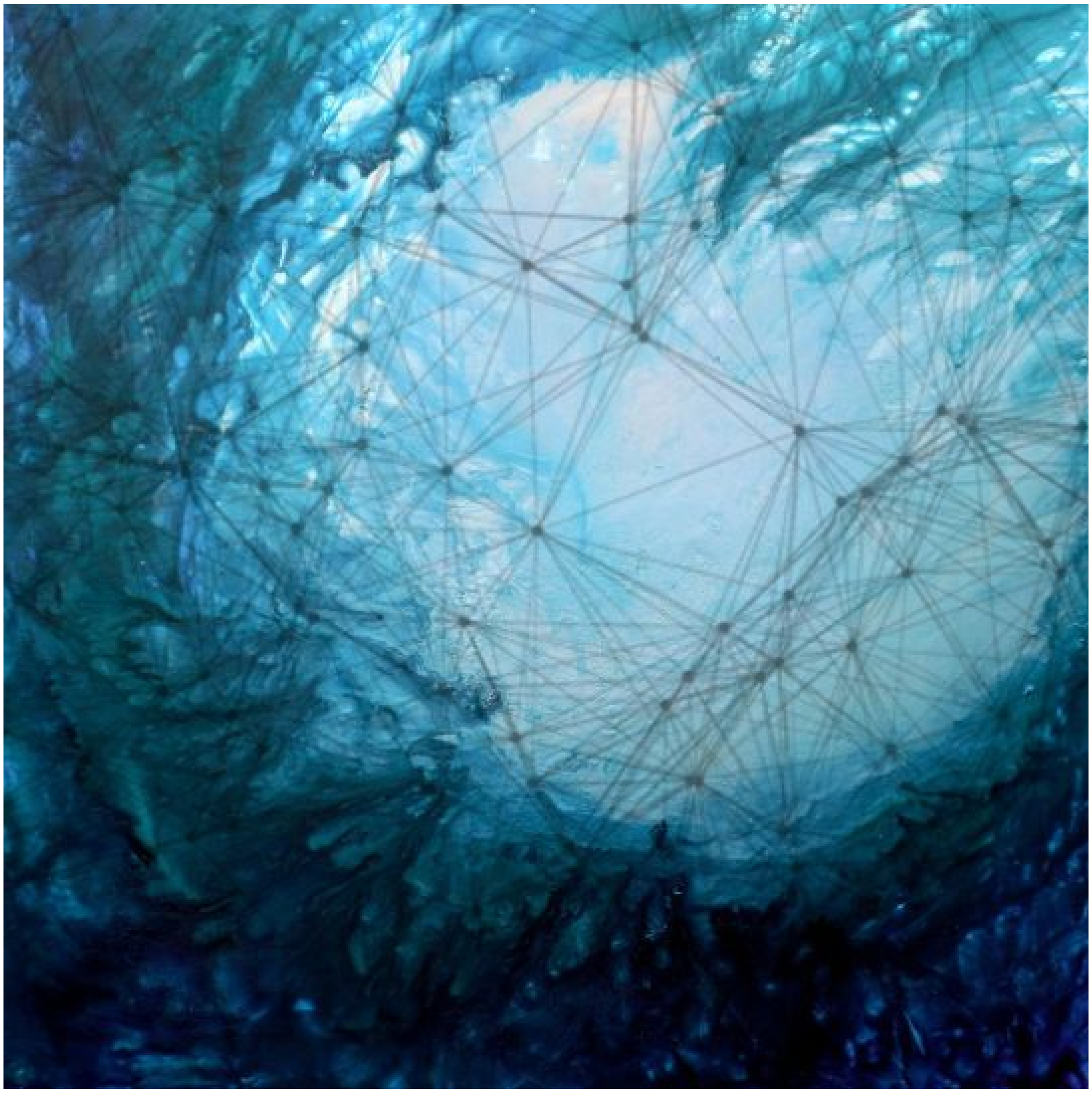
Jan 27, 2019 Aditya Nirgun

“Arrakis teaches the attitude of the knife - chopping off what's incomplete and saying: 'Now, it's complete because it's ended here." - Frank Herbert, Dune

Harsh sun bakes the Khezri Plain, a desert stretch in the South Khorasan province in Eastern Iran. Annual precipitation falls between [129 and 158 millimeters](#) in this region - virtually non-existent (average precipitation in Davis: 499.364 mm). Beneath this plain is an unconfined aquifer, a reservoir that directly receives surface groundwater and leads it out of the plain

Desolate. Hostile. Dry. Would you want perform an agricultural operation here? The challenge is daunting, seemingly insurmountable. However, an experimental attempt could reveal the capabilities and limits of agriculture in extreme environment conditions. To what end? In the most removed perspective, it seems doomsdayers and survivalists have their merits, specifically in their concern for sustaining crop production in the conditions of a Wasted Earth. Even without the fears of nuclear fallout or alien terraforming being pertinent, the clearer threat of accelerating climate change and nitrogen pollution could bring about apocalyptic consequences for access to clean water resources in many parts of the world. Experimenting today in the harshest landscapes on Earth could present an opportunity to engage in special preparation we may someday desperately rely on to keep up with food demand.

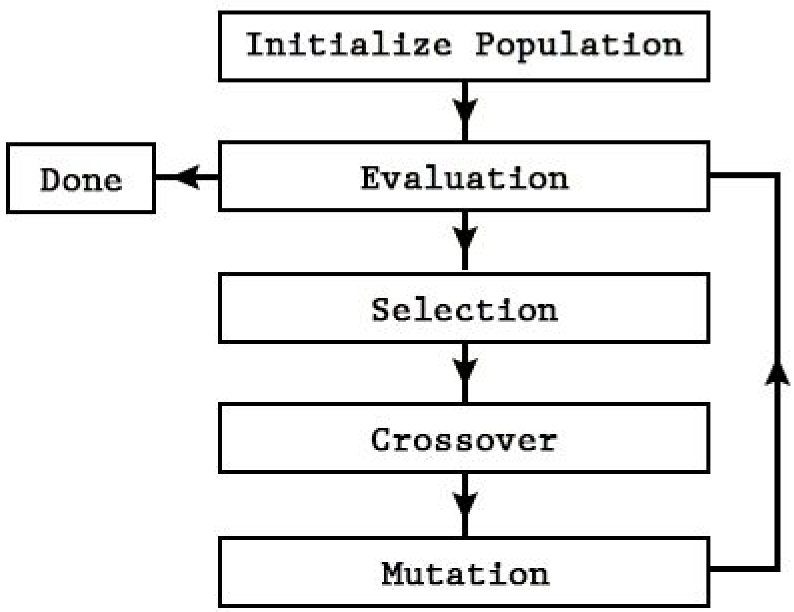
Going forward in our thought experiment, one would begin by assessing the quality of the natural resource that could be most limiting to production; in the Khezri Plain that resource is clearly water. Quality parameters important to agriculture include Total Hardness (TH), Total Dissolved Solids (TDS) and Electrical Conductivity (EC). Excessive hardness in water presents a problem with foliar deposits of calcium carbonate and magnesium. TDS that tests too high can restrict nutrient uptake and plant growth. High EC is an indication of high salinity that causes severe growth effects. These water characteristics are determined by a host of non linearly associated hydrochemical variables that interact in complex ways. This makes ecological investigations, diagnosis, and decisions supremely difficult in any location where water quality is a concern.



Edited painting by Holly Anderson

In a recent paper, Aryafar et. al. studied the basis of these three parameters in the water from 12 evenly distributed wells across the Khezri Plain. This sampling was conducted over a period of 10 years (2007 - 2017) where they gathered a total of 240 samples. They collected data on K^+, Na^+, Mg^{2+}, Ca^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, CO_3^{2-}, pH and temperature as input variables while TH, TDS, and EC were calculated directly. The intuition of the researchers was that these hydrochemical variables can be processed to produce a theoretical calculation estimating TH, TDS, and EC. This computational pursuit is weighed down, however, by the presence of extraneous conditions such as temperature, geological events, location and time. The functions involved would be so complex and have such great deviations and error that this study should have been dead in the water and abandoned. But that didn't happen. The researchers turned to a blossoming field in computer science and data analytics for an answer. The tool they introduced was Artificial Intelligence and they deployed several methodologies to tackle this problem, the most successful of which was the Genetic Algorithm. A genetic algorithm uses random iterative searches based on the concept of Darwinian win/loss conditions to formulate associations between independent and dependent variables - basically, it “thinks” through countless possibilities, checks the results, and builds upon its most successful returns in a brute force manner, completely avoiding the tangle of generalized theoretical models. The more it thinks, the better it predicts the expected outcomes.

GENETIC ALGORITHM FLOW CHART



For the study, this program generated associations between the hydrochemical data and the three parameters of interest that were reportedly remarkable and indicated potential for further use of AI in water quality testing, The associations produced by the genetic program were observed to have high R² values in the training phases, validation phases, and testing phases, with the highest for predicting TDS. The other AI techniques were similarly successful. With this kind of ability for prediction, local governments can manage groundwater resources on the chemical level. Virtual testing for water quality changes in response to pollution or climate change can lead to treatment solutions that can be deployed even before the worst of the damage is detected. With predictive data like this, the door to mastering preventive measures, terraformation, and sustainable agrosystems in harsh environments is now more inviting than ever.

Outputs	Inputs	Functions	Statistics		
			R^2	RMSE	MARE
TH	**Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^{2-}, pH**	**×, ÷, +, −, power, sin**	**0.983**	**51.38**	**0.093**
	Ca^{2+}, Mg^{2+}, CO_3^{2-}	×, ÷, +, −, ln, sin	0.952	66.29	0.104
	Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^{2-}	×, ÷, +, −, cos, power	0.891	82.18	0.137
TDS	**K^+, Na^+, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, CO_3^{2-}**	**×, ÷, +, −, sqrt, tan**	**0.990**	**121.35**	**0.041**
	K^+, Na^+, Mg^{2+}, SO_4^{2-}, Cl^-, CO_3^{2-}, T, pH	×, ÷, +, −	0.982	135.39	0.069
	K^+, Na^+, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^-, CO_3^{2-}, pH	×, ÷, +, −, tan	0.948	154.57	0.088
EC	**Na^+, K^+, Cl^-, Ca^{2+}, Mg^{2+}, T**	**×, ÷, +, −, ln, cos, sqrt**	**0.967**	**96.39**	**0.067**
	Na^+, K^+, Cl^-, Ca^{2+}, CO_3^{2-}, Mg^{2+}, SO_4^{2-}, T	×, ÷, +, −, ln	0.936	105.14	0.095
	Na^+, K^+, Cl^-, Ca^{2+}, Mg^{2+}, pH, T	×, ÷, +, −, power, ln	0.872	131.59	0.128

Table of the structure and the performance statistics of the genetic programming models during testing period (best models are shown in bold characters)

At this point in our desert adventure you may have the feeling that you have been tricked. This article should have been a treatise on cute, new desert farming practices but we now find ourselves in a strange, dark place where the world faces end times, a desert remains unsustainable for agriculture, and robots are analyzing the chemical content in water in ways that we cannot. In some ways, we could see how the discussion about the future of agriculture and the environment will always end up here. But maybe there's some hope here that, even without us, the world turns over and finds a way to continue.

Thank you for your attention and congrats on making it all the way here to the end. Here's a little [about genetic programming.]