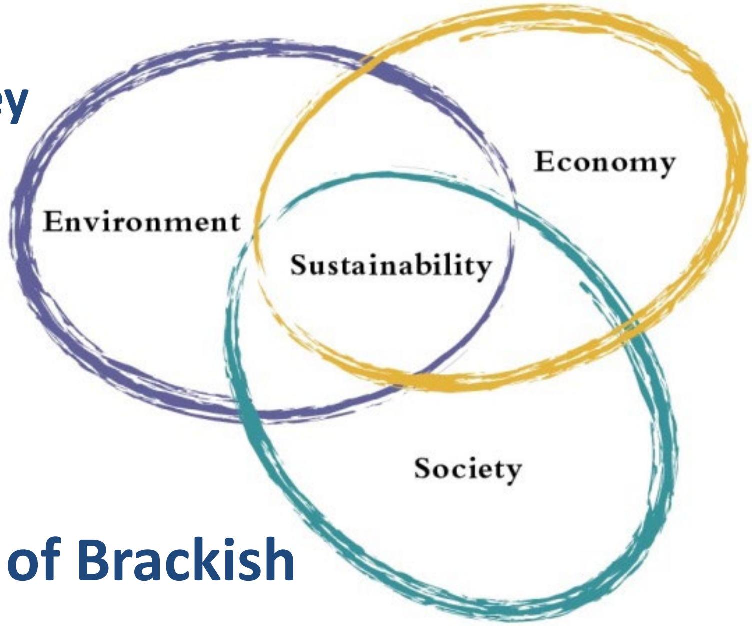
The International Conference “Groundwater, key to the Sustainable Development Goals”
Paris- France



Forward Osmosis Desalination of Brackish Groundwater in Egypt under the Framework of Water -Energy-Food Nexus

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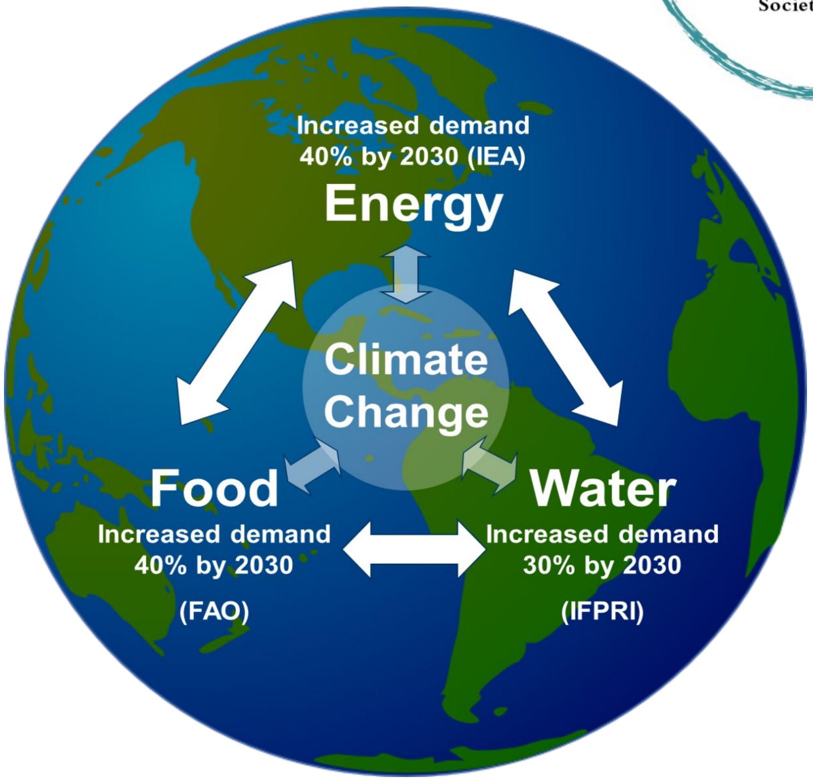
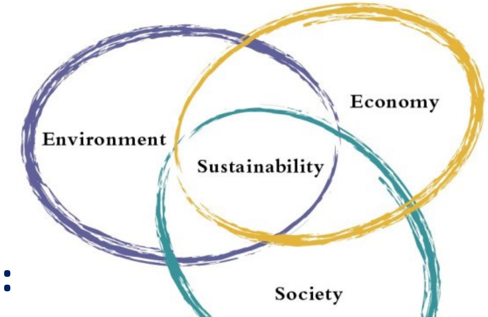
The Water –Energy-Food Nexus:

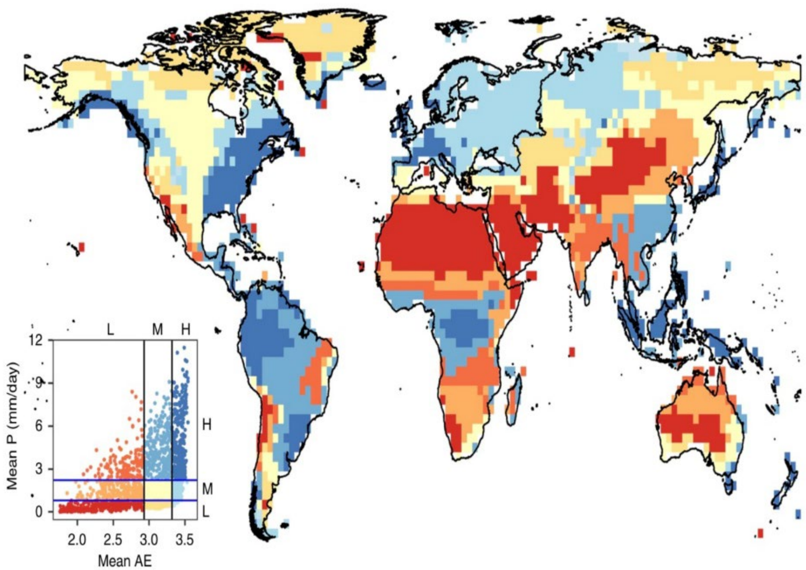
- Water, Energy and Food are Strongly inter-linked.
- There are significant challenges that affect the availability of these three areas.
- Currently, Solutions in one area often result in trade-off that negatively affect the other two.





Water Sustainability in Egypt:

Egypt is one of the countries facing water scarcity, not only due to its limited water resources, but also due to its dryness (UNESCO, 2012).



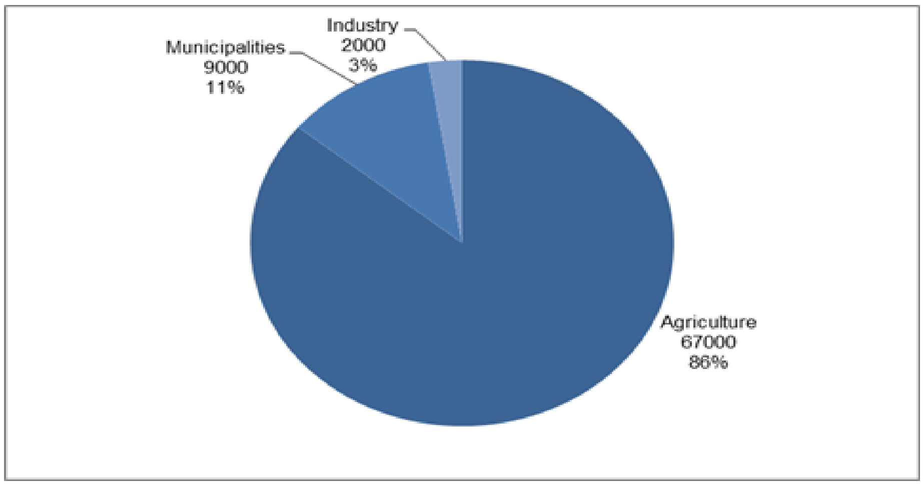
World Precipitation Rates (Konapala, G., et al, 2020)

Water Consumption in Egypt:

-Irrigation is the most significant water consuming activity which is about 85–95 %of the total consumption in Egypt(Nasr, Sewilam, 2015).

-Any minor irrigation water savings will significantly increase water availability for other users. (Nasr, Sewilam, 2015).

Water withdrawal by sector
Total 78 000 million m^3 in 2010



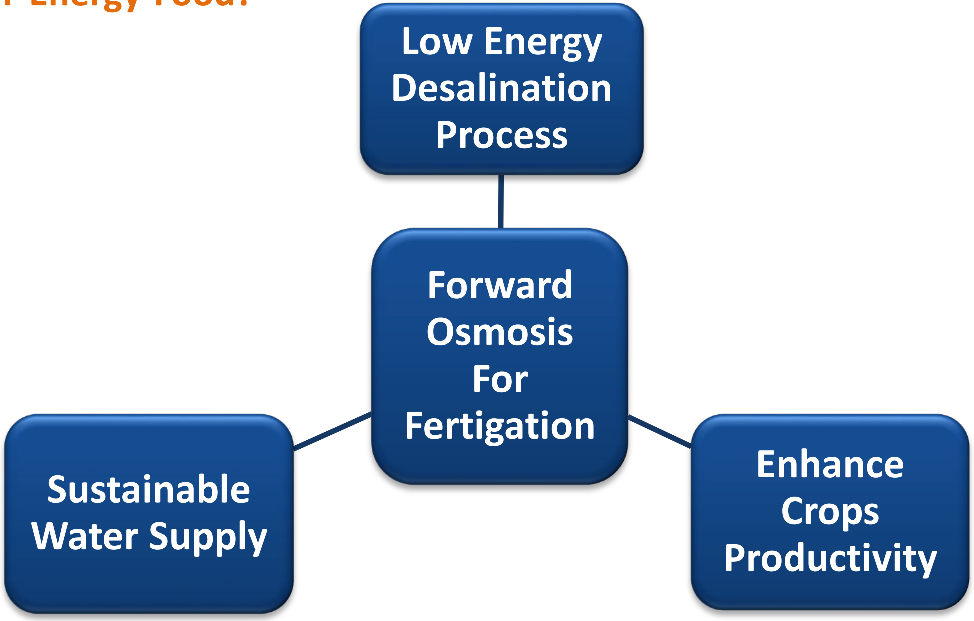
Research Scope:

Brackish groundwater from potential regions in Egypt are being desalinated using different types of fertilizers (Urea, Potassium Nitrate, Di-ammonium Phosphate) in addition to Hydroponics mixtures at different concentrations to determine their performance as Draw Solutions.

Research Outcome:

Obtain a full assessment and conclusion on the performance of different types of fertilizers and nutrients mixtures as draw solution to treat brackish and saline underground water in Egypt.

✓ **How the research achieves the Interlinkage between Water-Energy-Food?**



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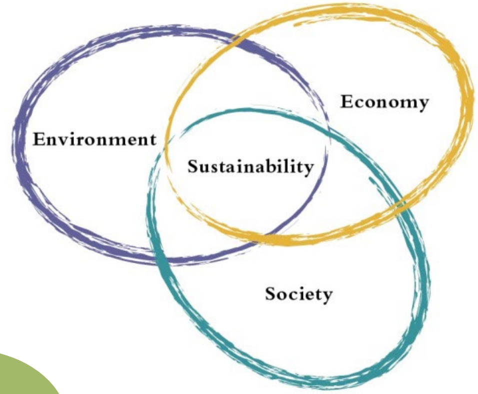

Research Purpose:

1

Test applicability of FDFO to treat real brackish groundwater in Egypt

2

Provide Assessment covering two agriculture techniques- (Soil and Hydroponics)

3

Provide Alternative Sustainable Water Supply under the framework of Water-Energy-Food Nexus

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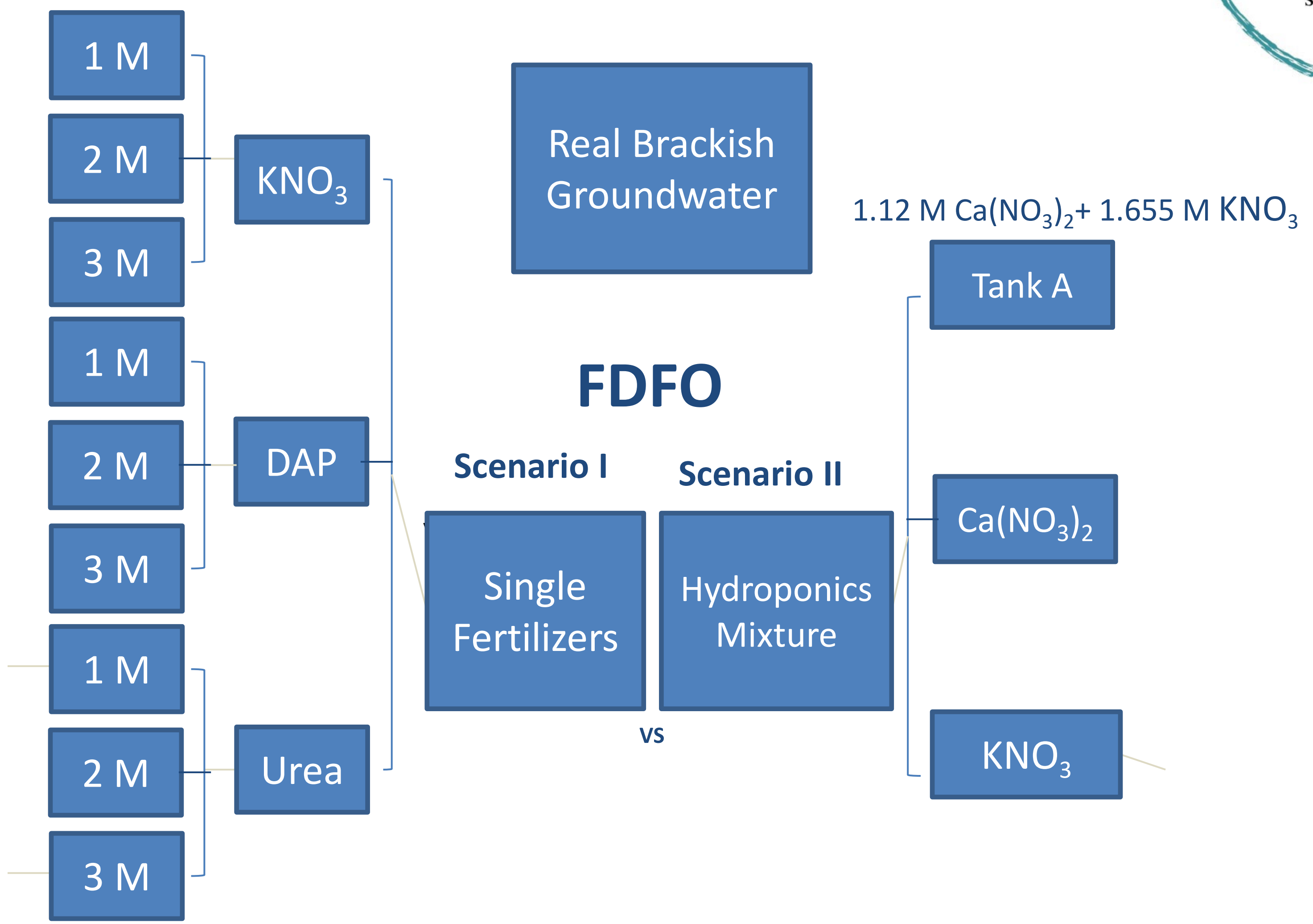
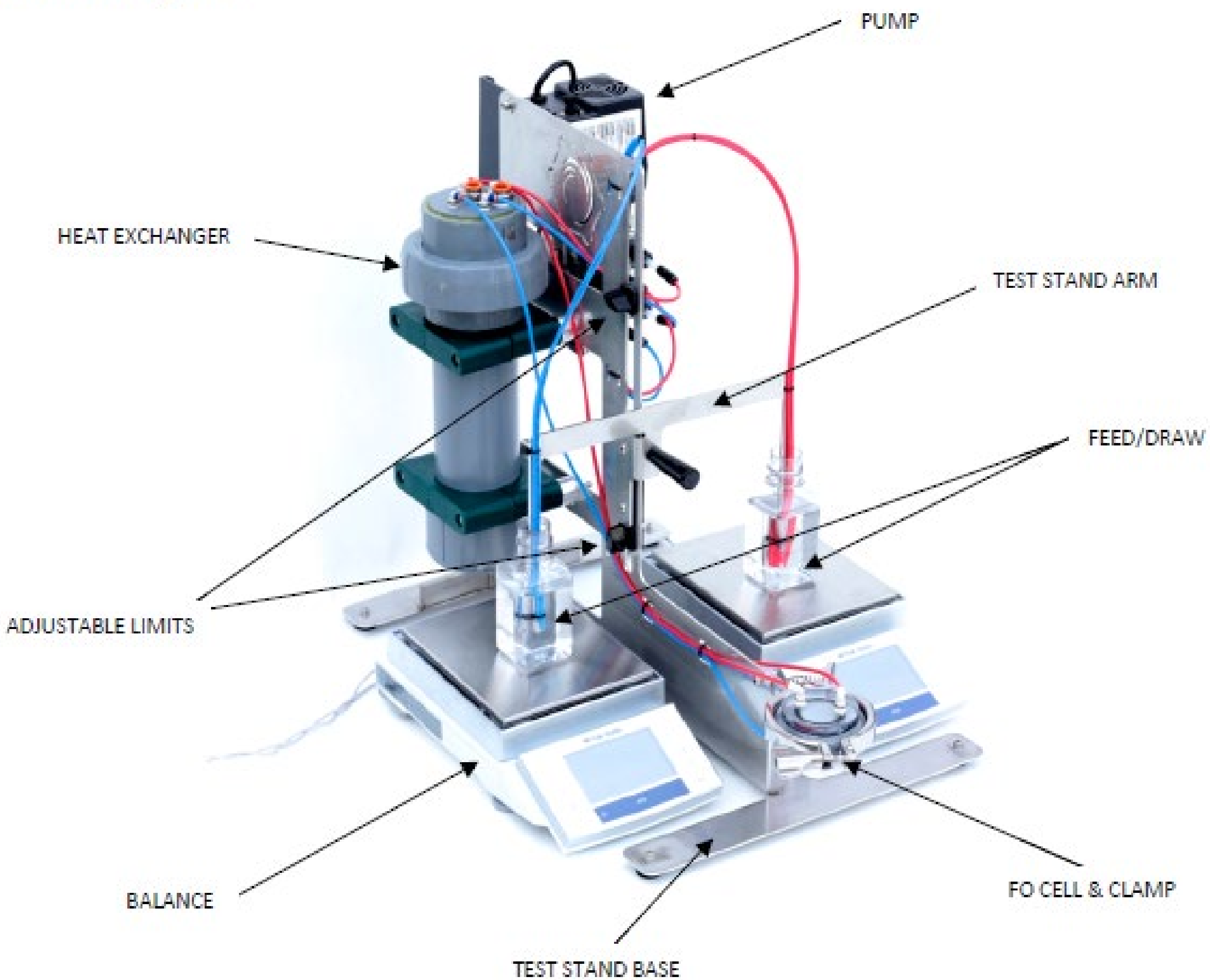
Environment Economy Sustainability Society

Methodology -The Experimental Plan:



Methodology (Cont.) Used Apparatus

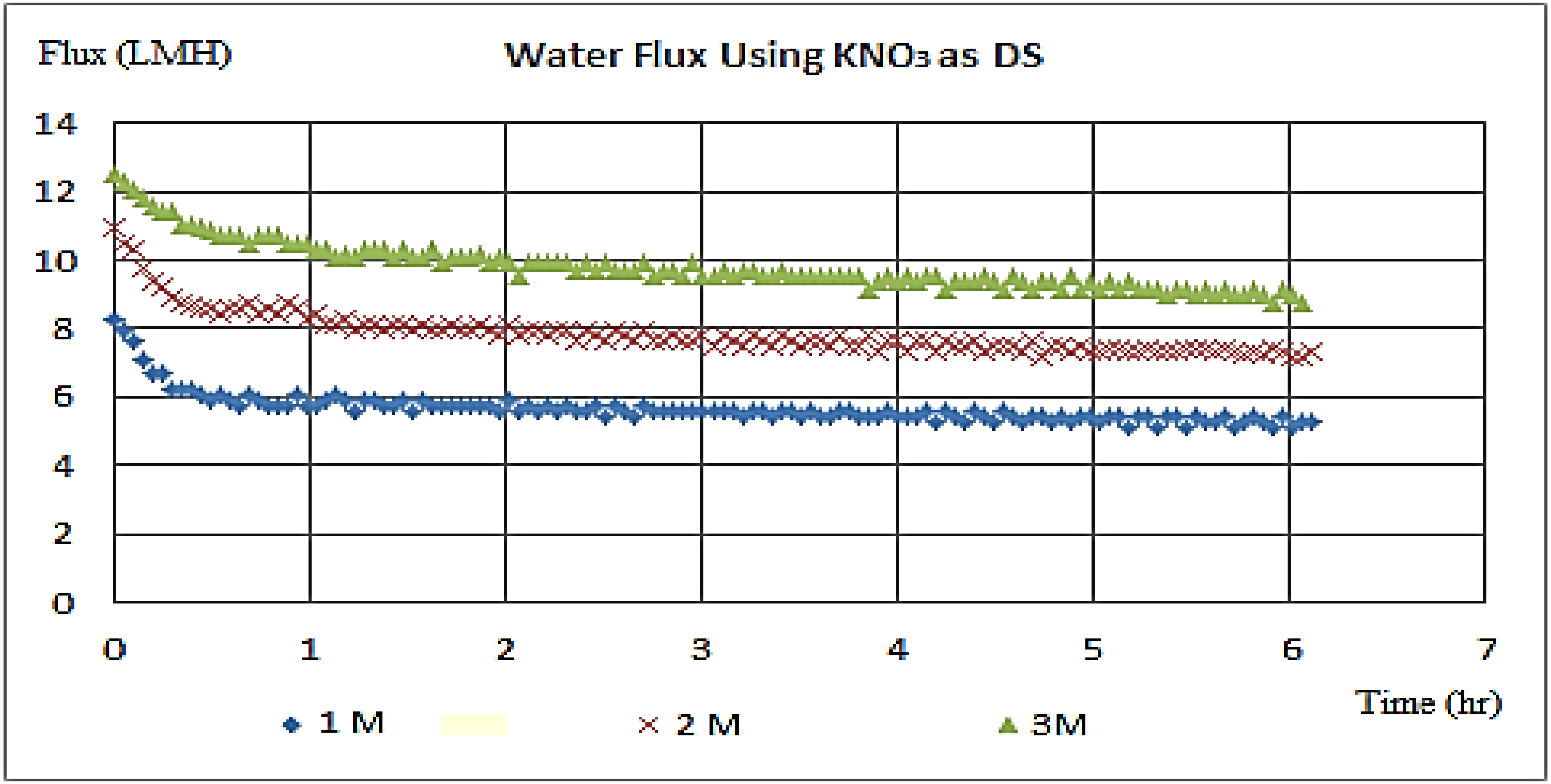


Fluxometer Set Diagram (Porifera Inc., 2015)

Results

Scenario I - Individual Assessment of KNO_3, Urea and DAP performance – Water Flux

1. KNO_3



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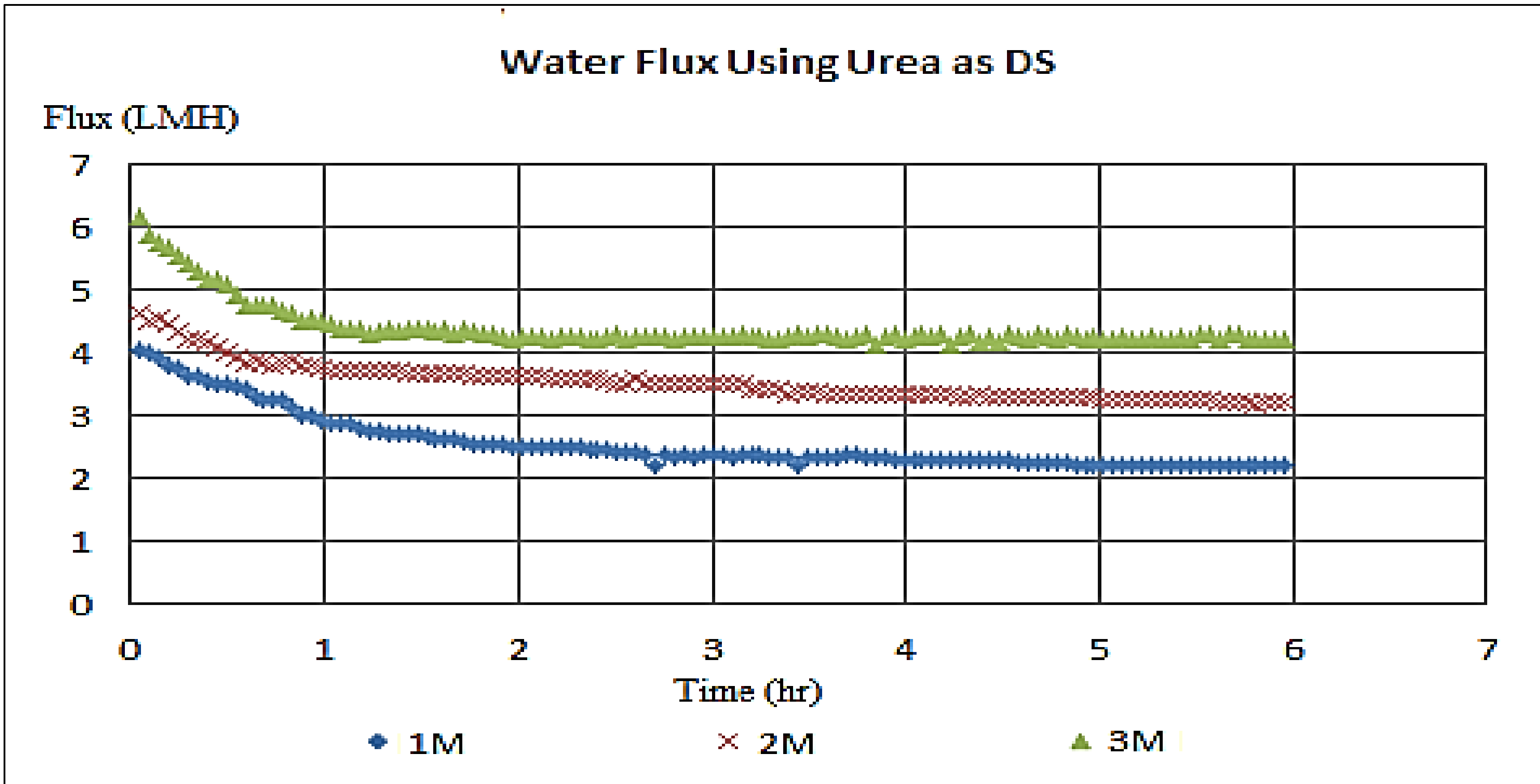
Results (Cont.)

Scenario I - Individual Assessment of KNO_3, Urea and DAP performance –Water Flux

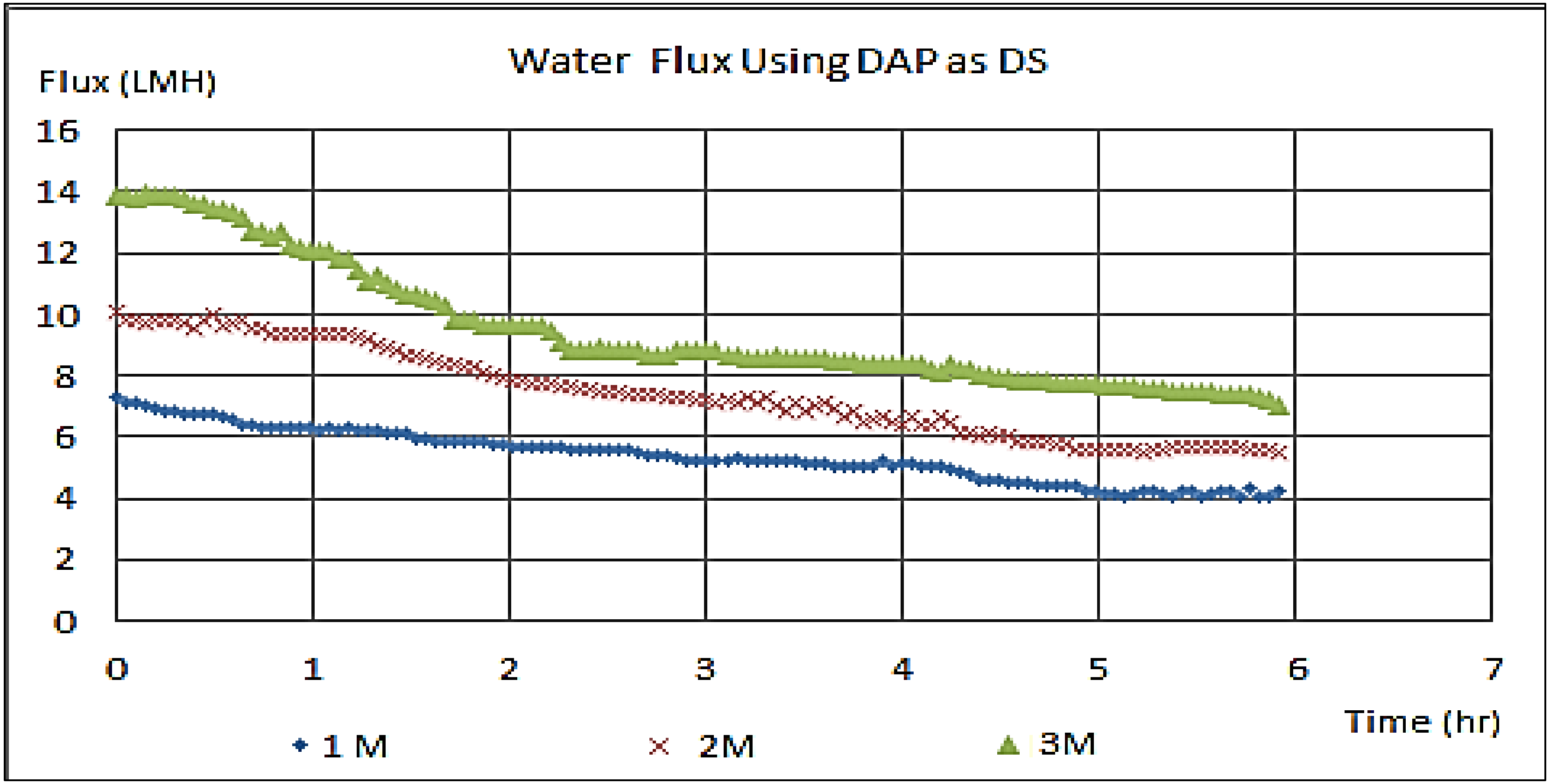
2. Urea

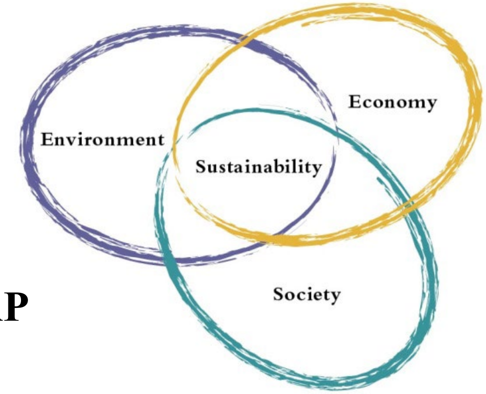


Results (Cont.)

Scenario I - Individual Assessment of KNO_3, Urea and DAP performance – Water Flux

3. Di-Ammonium Phosphate (DAP)

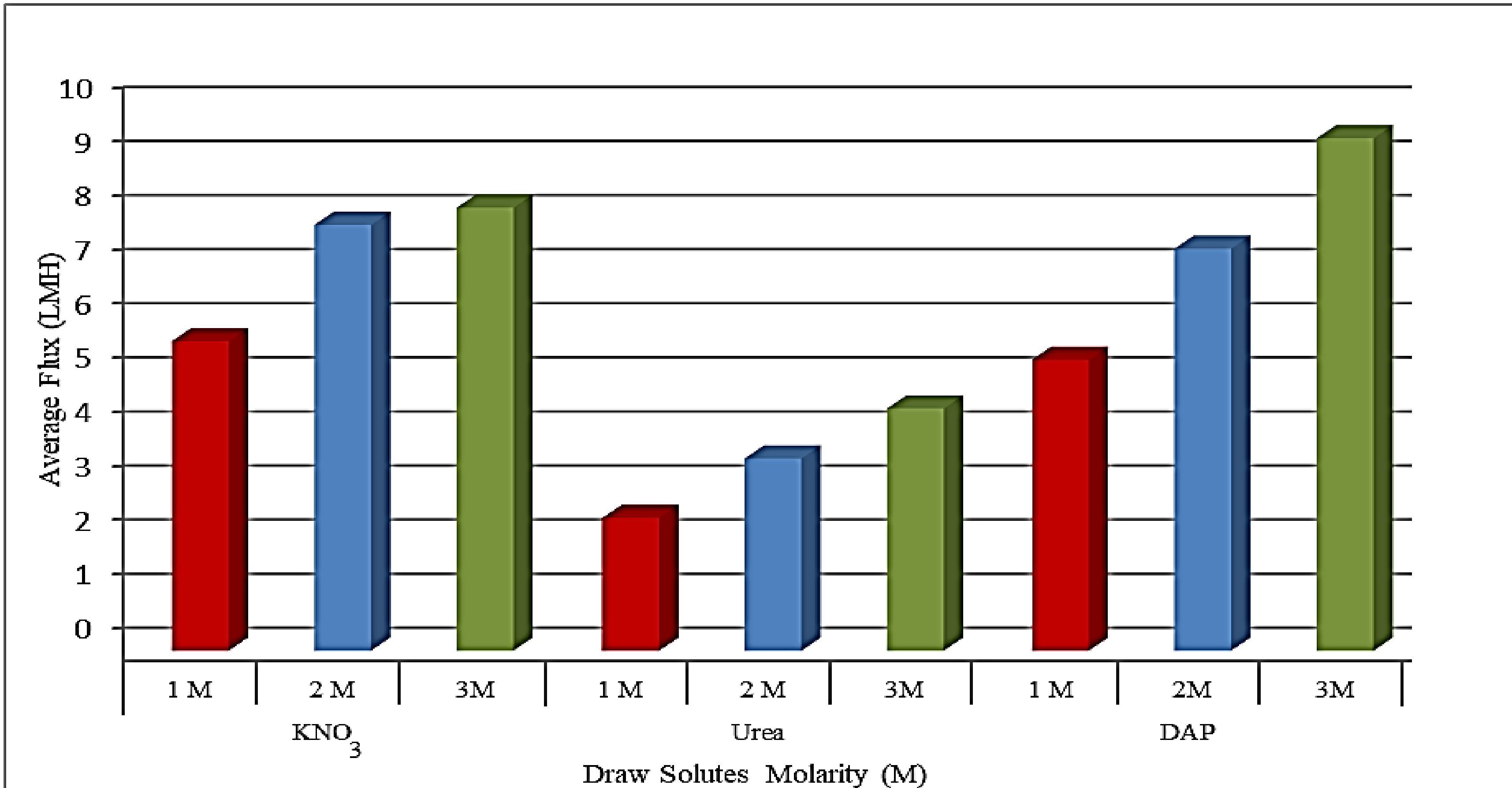




Results (Cont.)

Scenario I - Individual Assessment of KNO_3, Urea and DAP performance

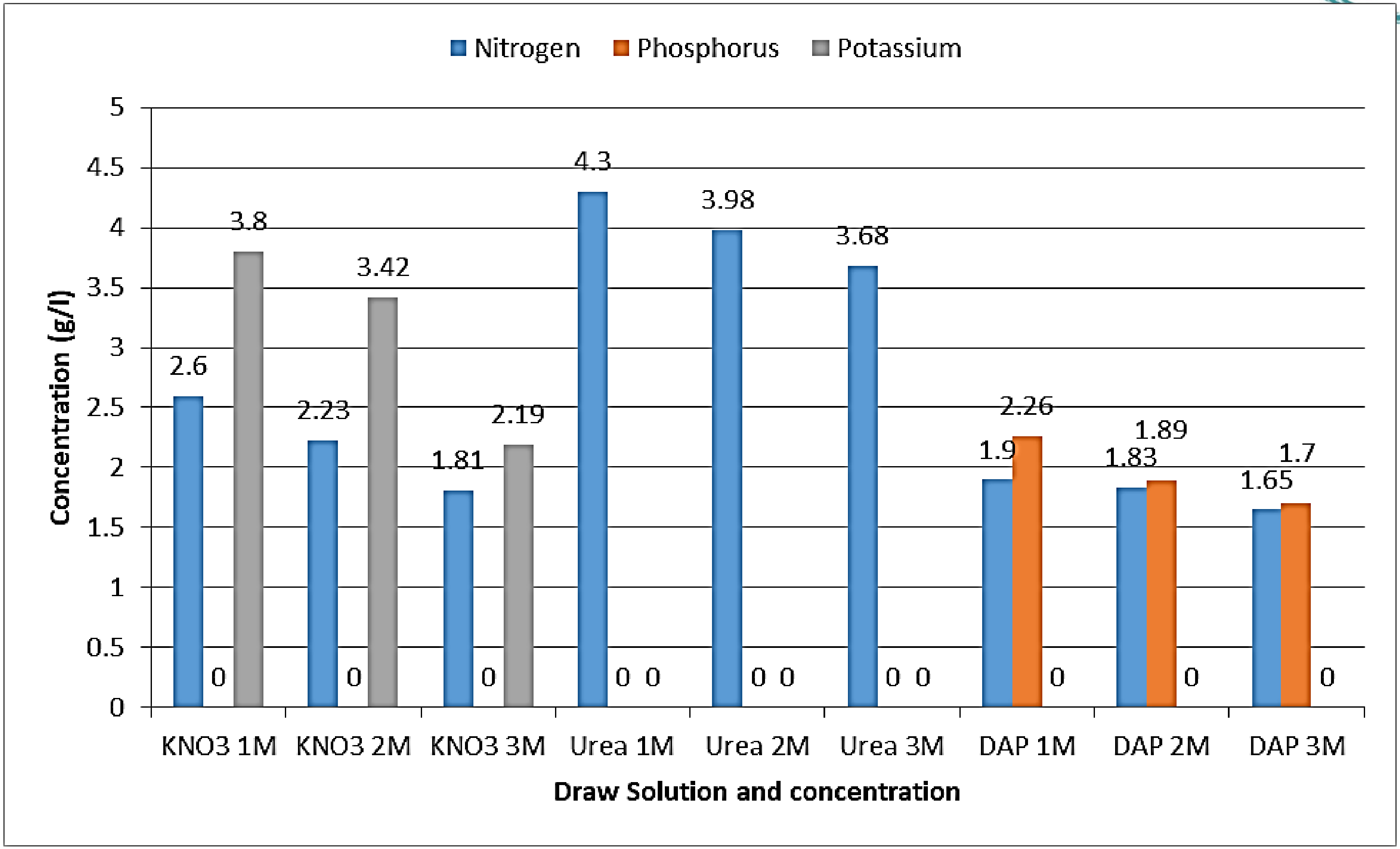
-Comparison between average flux of the three fertilizers



Environment
Economy
Sustainability
Society

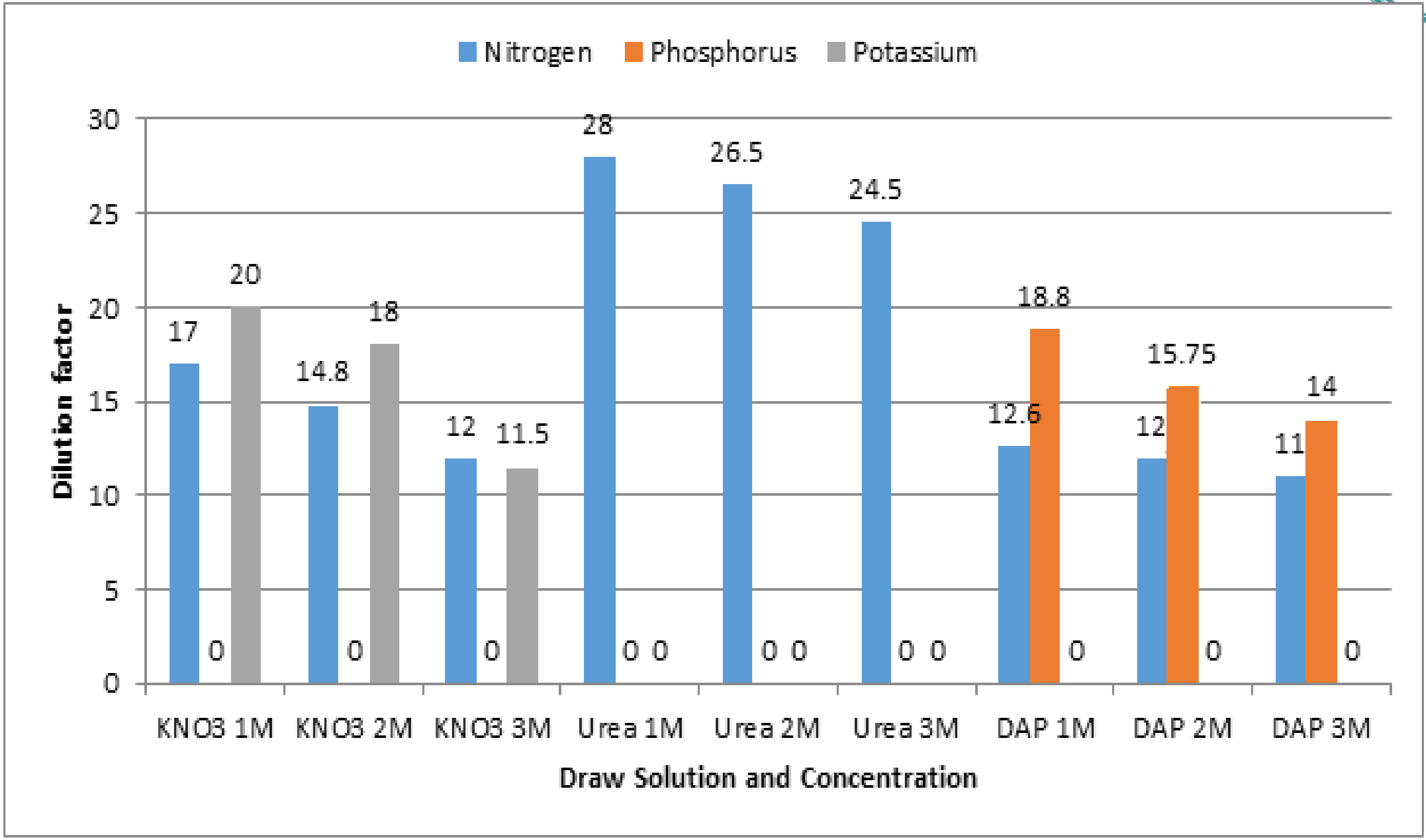
Results (Cont.)

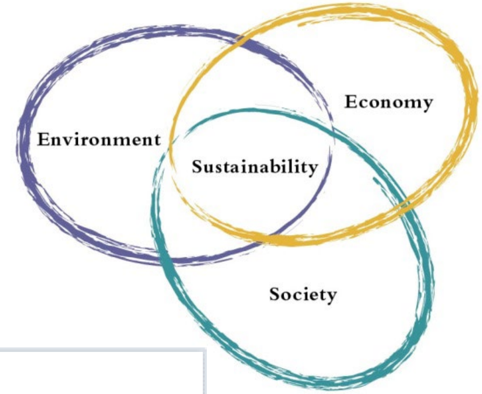
Scenario I - Individual Assessment of KNO_3, Urea and DAP performance - Draw Solute Concentration in Final Product Water



Results (Cont.)

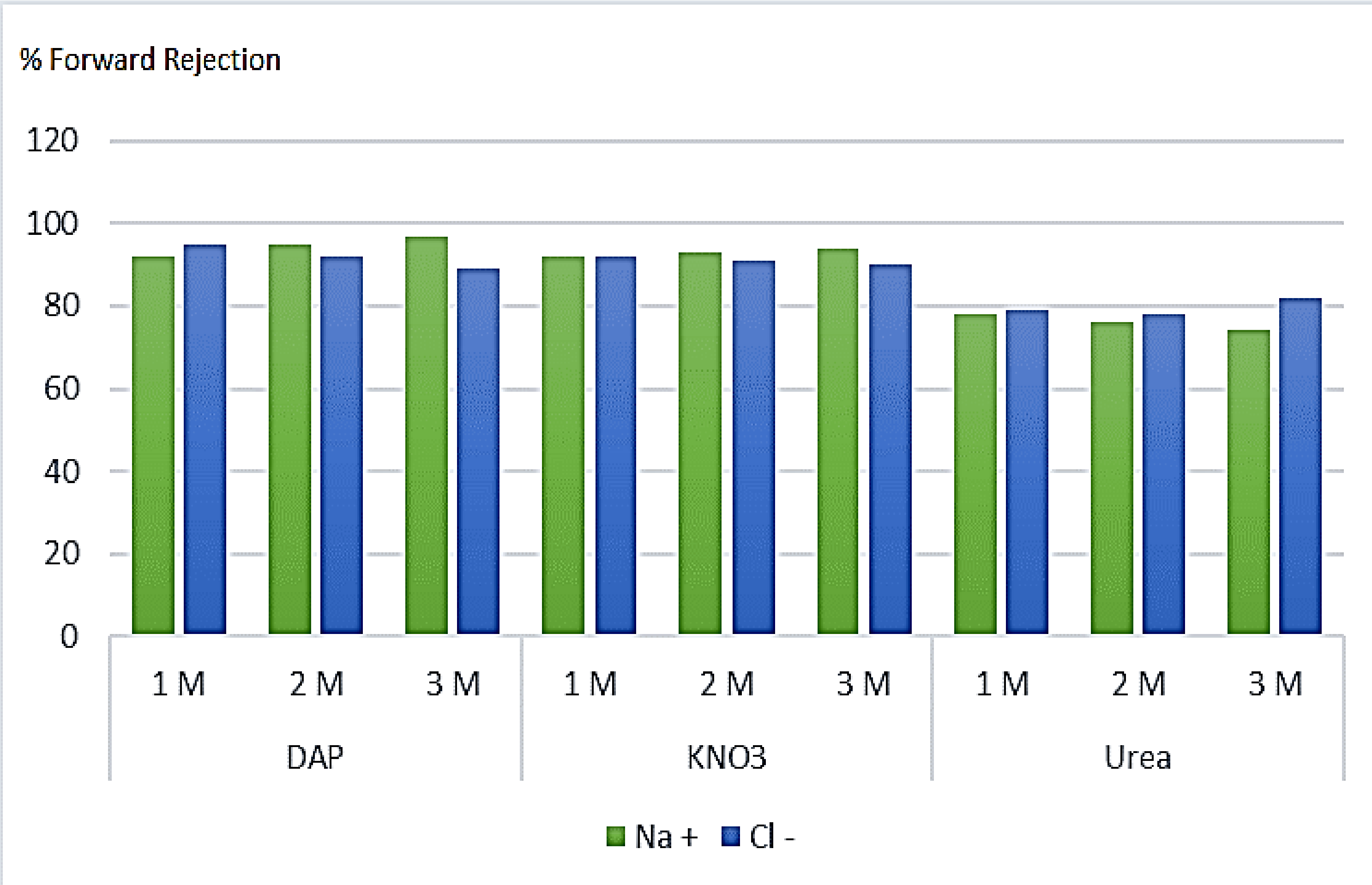
Scenario I - Individual Assessment of KNO_3, Urea and DAP performance - Required Dilution Factor





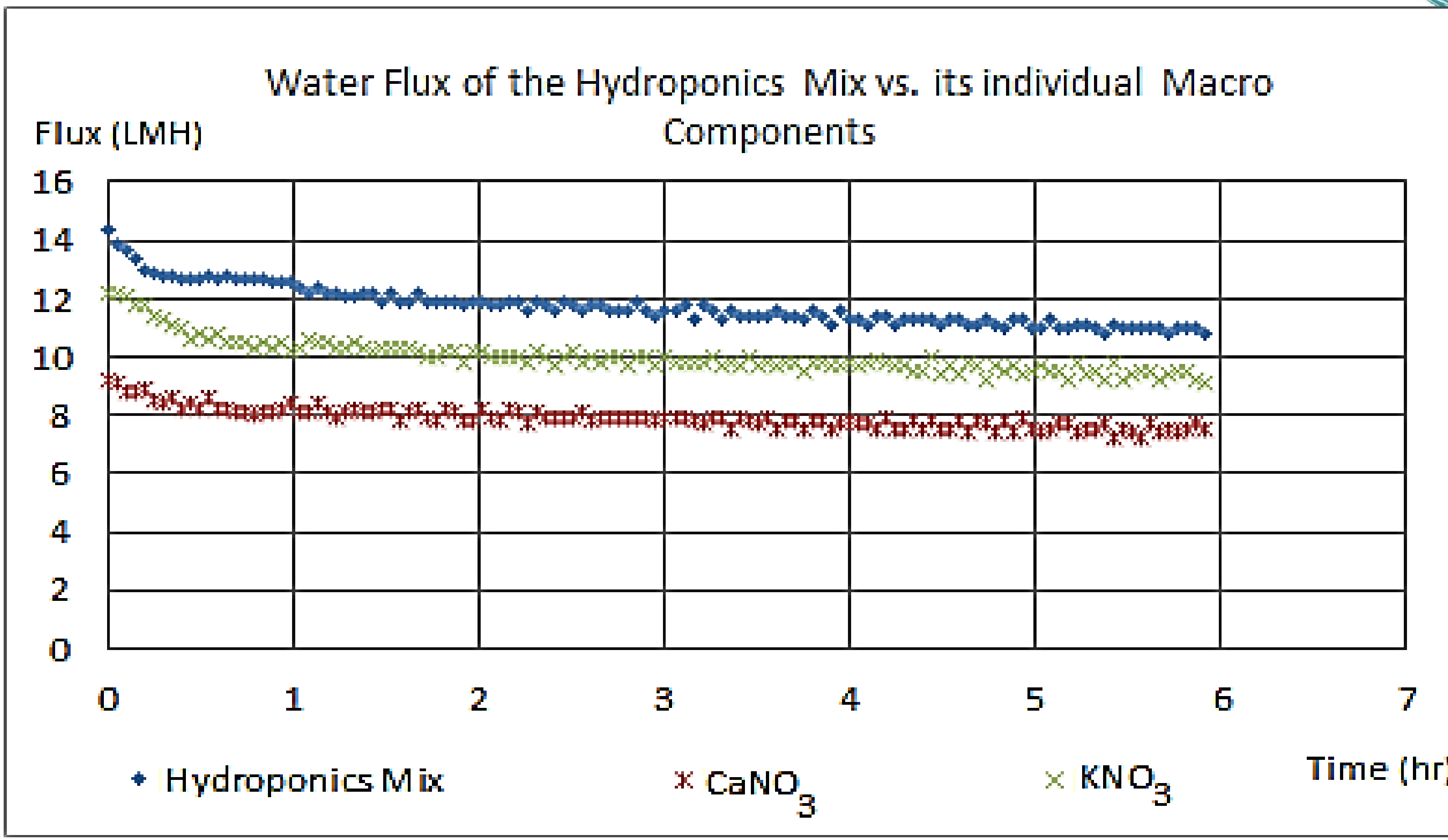
Results (Cont.)

Scenario I - Individual Assessment of KNO_3, Urea and DAP performance -Forward Rejection of Feed Na^+ and Cl^- ions



Results (Cont.)

Scenario II: The Hydroponics Mixture and its Individual Components: -Water Flux



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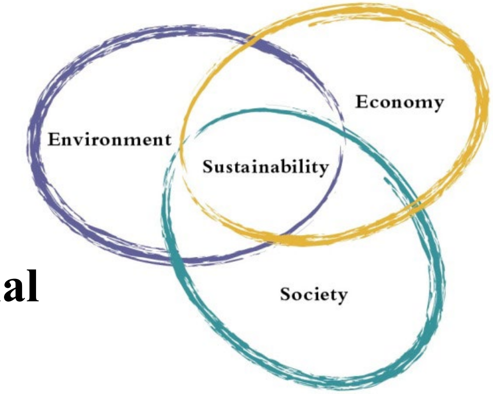
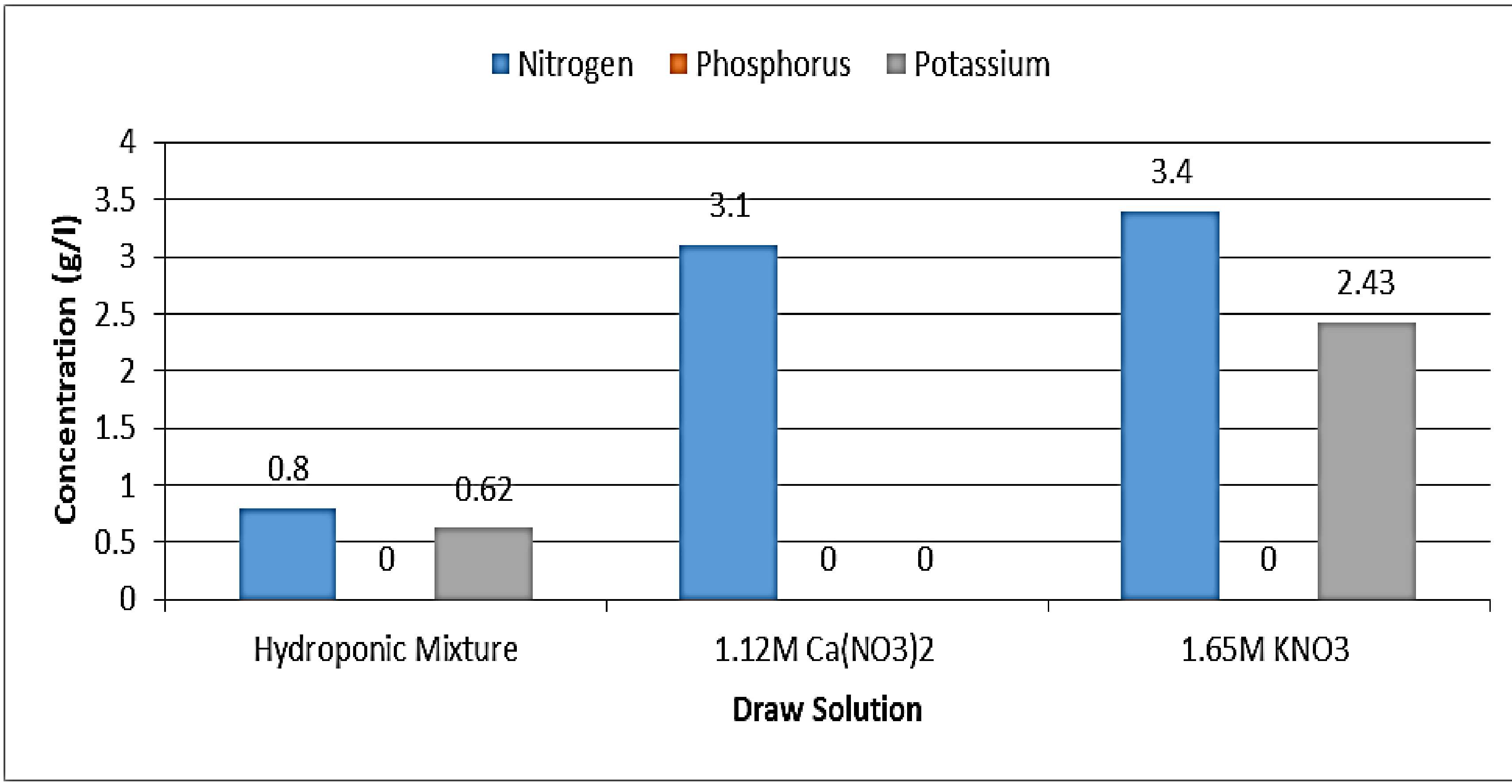


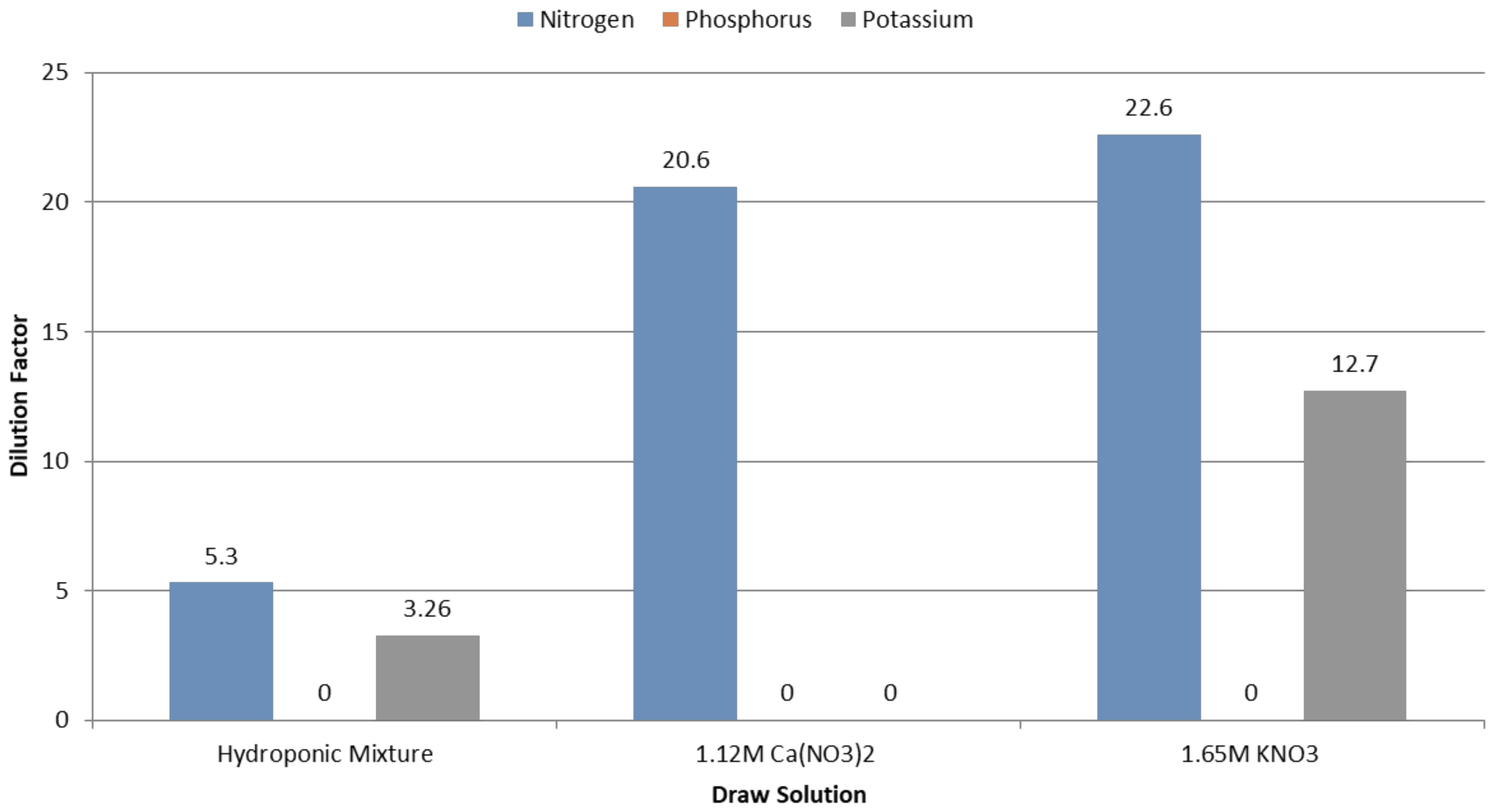
Results (Cont.)

Scenario II: The Hydroponics Mixture and its Individual Components: - Draw Solute Concentration in Final Product Water



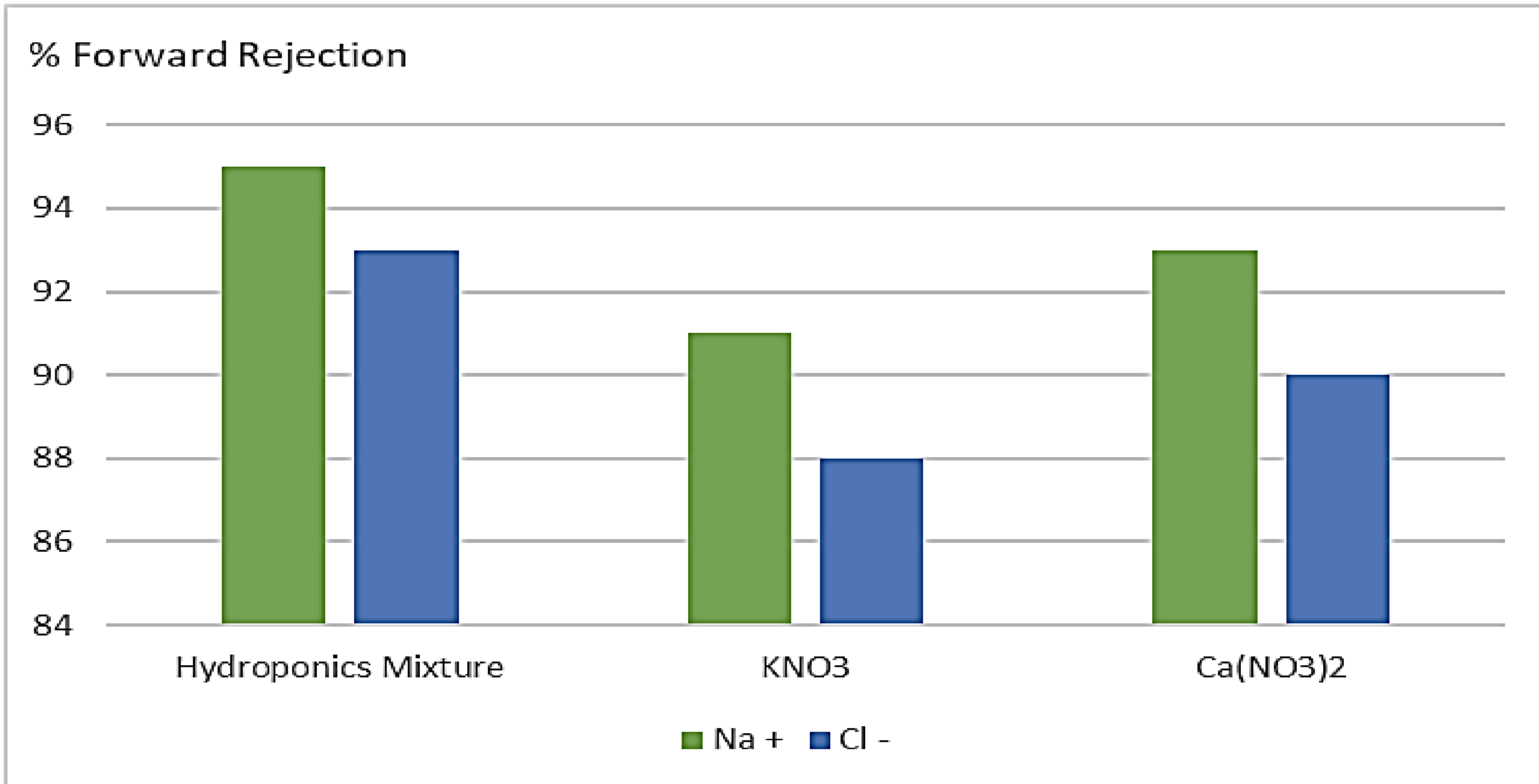
Results (Cont.)

Scenario II: The Hydroponics Mixture and its Individual Components: -Dilution Factor Required



Results (Cont.)

Scenario II: The Hydroponics Mixture and its Individual Components: -Forward Rejection of Feed Na^{+} and Cl^{-} ions

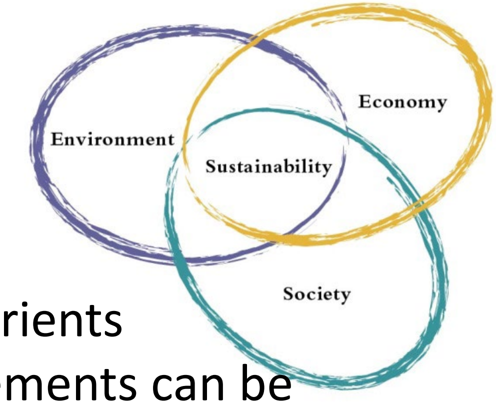


Discussion and Conclusion

- For First Scenario, DAP showed the highest water flux rate compared to the other two single fertilizers reaching 13.8 LMH, a feed ions rejection reaching 98% and acceptable concentrations of draw solute ions in the final product.
- Urea exhibited poor performance as a DS with a water flux as low as 2.2 LMH, low feed ions rejection equivalent to 78%, in addition to high DS solute in the final water product of 4.3 g/l, which agrees with (Phuntsho, Shon, Hong, et al., 2012).
- Hence, Urea solely is not a recommended draw solute for this application.
- In the Second scenario, Water flux of hydroponics mixture reached 14.35 LMH compared to calcium nitrate, which had the lowest value of 9.1 LMH and potassium nitrate with flux equivalent to 12.15 LMH.
- Nutrients mixture results exhibited a significant improvement in terms of the needed dilution to meet the crops fertigation requirement compared to the individual recipe components.
- E.g. for Nitrogen concentrations, dilution factor needed dropped from 22.6 to 5.3 when the hydroponics mixture was utilized.

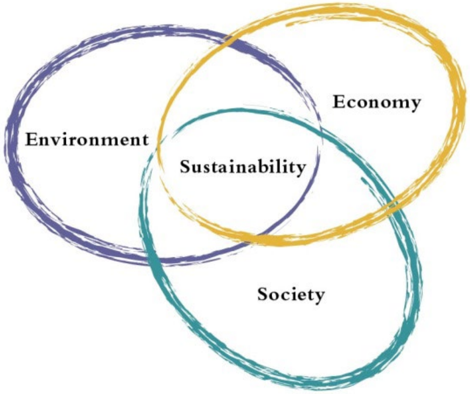
Recommendations

- For single fertilizers, it is crucial to select a draw solute with high molecular weight and larger number of species formation due to their vital impact on the performance during the desalination process.
- Fertilizer blending is recommended over the individual nutrients, Not Only due to the ability of the mixture to meet the plant nutritional requirements without the need of further addition of more fertilizers, but also due to the higher osmotic potential of the mixture and its ability to mitigate a major Forward Osmosis limitation, which is the need of product water dilution.
- However, it is advised to conduct a preliminary simulation to test the osmotic potential for each hydroponic recipe before testing to predict its adequacy as a draw solution and study its ingredients before blending to prevent salts precipitation due to the common ion effect.



Recommendations (Cont.)

- Regarding testing other hydroponics mixtures, creating nutrients recipes tailored to fit the Egyptian crops nutritional requirements can be very useful as an adaptation measure for climate change to boost crops productivity without compromising energy sustainability nor freshwater consumption in addition to overcome the challenge of the increasing land aridness.
- In summary, adapting forward osmosis desalination to produce diluted hydroponics nutrients mixtures for food production is a promising plan to tackle Water, Energy and Food challenges in Egypt.
- However, further research is needed to develop the FDFO technique in order to overcome its limitation regarding the after-treatment dilution requirements. Moreover, it is crucial to consider the interlinkage of the three WEF Nexus pillars while conducting further research in order to avoid tradeoffs that may occur if treated from water treatment perspective individually.



Thank You