Calculating Aquaponics efficiency and upscaling

Student Resource *(Draft: 2/28/2018)*

Purpose: To determine the impact of aquaponics on water usage and food availability. Learn to upscale a system by calculating using data from the 4 x 4 ISB aquaponics Data_2017 applied to a classroom. Then apply the skills to estimate the impact for a country for "Building Your Case."

- Calculate the water footprint of a crop grown in an aquaponic system
- Upscale the aquaponic model system for a school to estimate water and space(land) use to produce a vegetable crop to supplement the vegetable needs
- Upscale the aquaponic system model for a country to estimate the percent per year of water conservation and reduction of vegetable imports

PREREQUISITES:

- The systems thinking activity **"So, What is Aquaponics?"** to introduce the science behind aquaponics. A basic understanding of farming methods and irrigation use from **Lesson 2**

INSTRUCTIONS:

1. **Gather information:** Recall how aquaponics compares to more traditional irrigation- and fertilizer-dependent farming methods (see **Lesson FS2**). Use the evidence from real-life model: ISB aquaponics Data_2017 or a class system, to compare water use and plant production. Summarize the **Final Data:**
   a) The total input of water in this aquaponic system was _____
   b) The aquaponics system produced _____ kilograms of (**crop)** that is consumable.* (**wet mass is what you eat, dry mass is used for calculating calories)*
   c) How much of the plant is available for consumption? Why would we want to leave some of the plant in the system?

2. **Diagram of A Solution**: Make a plan to upscale aquaponics, first answer the following:
   a) How can an aquaponic system be applied to a food system for a country?

   b) What positive effects could these model systems have on a country's food growing system? Give evidence of how aquaponic system models could help measure or compare these positive solutions.

3. UPSCALING THE SYSTEM: *Your aquaponic system used a measurable amount of water and space to grow the vegetable(s). The World Food Program(WFP) "Field-to-Table school field program" estimates children need **30 grams per day of each vegetable to have a healthy diet (adults do too!).** To meet this need, but reduce water use and imports of vegetables, how could aquaponic systems be applied to a food production system? To collect evidence, answer the following:*

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Testing A Solution: "If we need 30 grams of lettuce per person per day for a year - we could save water if we used aquaponic systems to produce the same amount of lettuce." **To test this idea do the following step-by-step calculations to see how much would be conserved. (Watch your units carefully!):**

a) What is the water footprint of the (lettuce) crop for this aquaponic system? The system used a total of: _____ liters/kilogram of food (ex. lettuce) produced. Show your Calculations here: (Convert liters/gram to liters/kilogram first. (1 g = (1/1000) kg = 0.001 kg.)

$$\frac{\text{Liters total water used}}{\text{kilograms of crop (biomass)}} = \text{aquaponics L/kg water footprint}$$

b) How efficient is the aquaponic system in reducing water use to produce lettuce? What is the ratio of water use between the soil-based global water footprint and aquaponic water footprints? *(Compare aquaponic water footprint : Global water footprint. See* "The green, blue, and grey water footprint of crops and derived crop products" (Fig 3, p. 1588, M.M. McKennon & Hoekstra, et al (2011) or use "Water Footprint of Food product gallery" website.)
Show your calculations here:

Lettuce aquaponic system water footprint is_____ (liter/kg)

Lettuce soil-based farming global water footprint is_____ (liter/kg)
(*Source: M.M. McKennon & Hoekstra, et al (2011))*

c) If we upscale the aquaponic system model to country-wide use what would the percent of water used? Use this ratio to estimate the percent water use increase or decrease.

$$\frac{\text{aquaponics water footprint}}{\text{global water footprint}} \times \frac{X}{100} = \_\_\_\_\_ \text{ \% water use consumption}$$

100 % – _____ % water use consumption = _____ water reduction

d) What else did the ""The green, blue, and grey water footprint of crops and derived crop products" **" scientific study or "**"Water Footprint of Food product gallery" **" include in calculating the footprints that we did not include in the aquaponic system water use calculations? How is water lost in aquaponic systems?**

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4. If a drought occurred the school would start to conserve water to help keep the system from breaking down. Schools also want to reduce the "importing" of vegetables by growing them nearby, which both reduces transportation costs to the school and provides healthier food. Make a plan to install more aquaponic system(s) in classrooms to reduce water use and vegetable imports. Assume the school serves 30 grams of salad for 100 student lunches each day for 185 days. Using the model aquaponic system describe the plan and show your calculations.

a) How many 4 x 4 aquaponic systems are needed to produce enough grams of this crop for the population per school year?

c) **How much volume of water (m^3) would be needed to keep the aquaponic systems operating to produce the crops over the school year? Show calculations.** *(1000 liters = 1 m^3)*

c) What proportion of the total school water use is <u>conserved</u>, using aquaponics?
Compare the water used in aquaponics to the traditional global water footprint to produce the required amount of the crop. *(Calculated global water footprint of lettuce = 237 liters/kg)* How does each compare to total school water withdrawals?* *According to Farina, et al in a study of water consumption in U.S. public schools "[....] basic demand for water is estimated as [.....] *18 liters per elementary school student per day."* (**Farina, M. et al.,** *Procedia Engineering* **Vol. 21, 2011**)

4 x 4 m aquaponic systems use _____ (m^3) to produce 30 g of lettuce per lunch/per day/per school year.
Global Water footprint would use _____(m^3) for 30 g of lettuce per lunch/per day/per school year.
School water withdrawals for the school year average _____(m^3) *(100 students x 18 liters/student/day x 185 days)*

_____(m^3) of aquaponics water footprint_
_____(m^3) total water withdrawal of school

vs

_____(m^3) global water footprint_____
_____(m^3) total water withdrawal of school

= _____ (ratio water use/annual withdrawal)

= _____ (ratio water use/annual withdrawal)

d) **How many metric tons of lettuce would this provide?** *(1 metric ton = 1000 kilogram)*

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5. The *Waterfootprint.org website says:*
"The global average water footprint of lettuce is 237 liters/kg (*updated 2011). However, the water footprint is different from place to place. For example in China and the USA, the two largest producing countries, lettuce has a water footprint of 290 and 110 liters/kg, respectively."*

a) Why do you think the average soil-based water footprint of lettuce is different in these two countries?

b) Do you think aquaponics would have more or less water footprint stability in two different countries? Explain your answer.

6. Other than cost describe two positive impact(s) using aquaponic systems have on a food growing system. And what are two unintended consequences? Explain.

Positive impacts:

Unintended consequences:

*STOP HERE AND GO TO "BUILDING YOUR CASE" TO ANSWER THE REMAINING QUESTIONS

UPSCALING FOR A COUNTRY ("BUILDING YOUR CASE")

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INTRODUCTION: *How do the aquaponic systems fit into the bigger picture?* Work in groups of 2-4, to upscale *the aquaponic system model, using the "school-scale" calculations as a guide. How much could aquaponic systems reduce vegetable imports? Estimate the percent per year of water conservation for the country. How else could the systems affect food availability in the country? Provide evidence. Use UN FAO data queries for Namibia, Haiti, and DPR Korea: Water use summary and Vegetable import and production. Keep track of your units! Show calculations and record results in "Building Your Case"*

1) How many 4 x 4 aquaponic systems should be built to feed the total population 30 grams per person per day of the vegetable (eg. lettuce) for a year? *Using lettuce as model crop: the number of crops per system and harvest is 1 x month, so assumer 12 harvests per grow bed per year.*

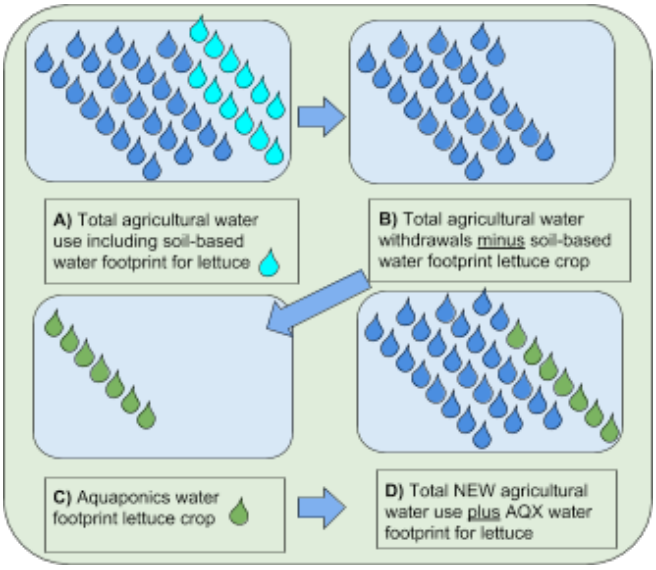
2) How much volume of water in meters cubed (m^3) would be needed to keep the aquaponic (AQX) systems operating to produce the vegetable crop (eg. lettuce) to feed the population over a year? Compare this result to soiled-based farm methods for the lettuce crop *("Soil-based water footprint" is used as equivalent of Global average water footprint for this activity**)***. Show your calculations.**
(1000 liters = 1 m^3)

- **Aquaponics (AQX)(Liters) of water converted to (m^3) = _____**
- **Soil-based Water footprint (Liters) of water converted to (m^3) = _____**
- **Ratio (water use Aquaponic system : Soil-based water footprint) = _____**
- **Is the ratio the same as the classroom scale?**

3) Drought could reduce the total Internal Renewable Water Resource by 30% over 5 years —will the addition of this aquaponic system increase security to the system? ***(****Producing 30 grams of the vegetable crop (eg. lettuce) per person per year)*
**Agricultural water withdrawal is the equivalent water footprint for soil-based water footprint:*

a) **What percent of the *total Agricultural water withdrawal** is conserved, for other uses?**

b) Aquaponic (AQX) system designs, if highly engineered with additional improvements, can have a 98% water use reduction. Calculate how this improved system would compare.



For country calculations (a) and (b):

A) ***Agricultural water withdrawal** = _____*
B) ***Agricultural water withdrawal minus Soil-based water footprint of (crop) = _____***
C) **AQX (crop) water footprint = _____**
D) **AQX plus *Agricultural water withdrawal** for the country* = _____**

Ratio of AQX + Agricultural water withdrawal (D) to Agricultural water withdrawal (A) = _____

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c) How much of the *Total Internal Renewable Water Resource (IRWR)* for the country is conserved, if this aquaponic system design is applied to the food growing system?
*(*See UN FAO AQUASTAT Water use summary data)*

- **AQX systems water footprint** : _____ for 30 g of lettuce (population/day/year).
- **Soil-based Water footprint :** _____ for 30 g of lettuce (population/day/year).
- ***Total renewable water resources (IRWR)***: _____

4) For your country, how many tonnes of lettuce would the aquaponic systems need to produce if growing 30 g of lettuce per person, per day? What percent of the country's annual total imports for vegetables* is this? (*See UN FAOSTAT Vegetable import and production. (1000 tonnes = $1e_6$ kilograms)*

5) How do the aquaponic systems fit into a country's food system for reducing imported crops and conserving water? How would you plan to use them? Describe in a paragraph: where?, how? and why? Justify your answers.

6) Record the results in "Building Your Case"

Country	***Ratio AQX + Agricultural water withdrawal (D) / average Agricultural water withdrawal (A)***	***Ratio AQX system water footprint / Total water IRWR (m^3)***	***Percent of annual total imports for vegetables produced with aquaponic systems***
Soil-based water footprint	(1.00) or 0 conserved	0.217	NA
Haiti			
Namibia			
DPR Korea			

Summative question: (for class discussion)
Is an investment of money to develop aquaponic systems in the country going to lead to a significant decrease in water resource use for the country and therefore increase food security? (Think: *If the country can produce 30 grams of lettuce per person a day using aquaponics (to meet a basic daily dietary requirement) will this increase food availability and lower the use of water resources for food growing overall? Is this an increase in efficiency of the food growing system in terms of Money? Arable land? or Water? or a combination of these?*

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EXTENSION QUESTIONS:

A) How much money* could be saved using aquaponic systems to produce 30 grams of vegetables per person, each day? Vegetable market costs fluctuate because of which variables? (*see *FAO STATS for data)*

B) In a country where people have to spend approximately ¼ of their daily income and walk miles to collect safe drinking water —would aquaponics increase or decrease food security?

C) How would your configure enough 4 x 4 meter grow beds in the average classrooms to reduce the import of a vegetable? *(draw a class layout plan to scale on 8.5 x 11 in. graph paper)*

D) How much farmland could be used for other crops if we upscale the AQX system to produce this one vegetable crop? *(Compare the calculated amount of growing space to the total hectares* used for traditional methods of growing vegetables in a country (* FAO STATS for data)*

E) What is the savings for fertilizer costs to the country?

F) ***Extension APES:*** *Calculate the projected population over 10 years. What is the effect on water use?*

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