EQCom: an education and outreach simulation game for enhancing environmental quality in the commons

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Abstract
EQCom is a simulation game for teaching the effects of conventional farming on natural resources and the social challenges involved in implementing solutions. Players are "farmers" who make a series of choices about farming practices, either conservation or conventional. Outcomes result based on those choices and they include aesthetic and economic consequences. Farmers and society prosper if farmers collectively implement conservation practices and protect common resources, but a farmer's natural economic incentive is to make choices based on short-term private economics benefits instead of long-term private and public benefits. The natural progression in this game is for soil, air, and water resources to degrade and socio-eco-systems to suffer. Farmers will find over time that short-term economic gain must be sacrificed to achieve long-term sustainability and success. Farmers must regulate themselves or be regulated by government to succeed. This is a novel and exciting way to teach students, farmers, policy makers, and others about the complexity of conservation farming. Restoring environmental quality in the commons requires counter intuitive thinking, self-regulation, and consideration of public interest.

Key Words
nitrogen, phosphorus, soil quality, water quality, air quality, tragedy of the commons,

Introduction
Nearly 70 years after Aldo Leopold's bold call to action, conservation efforts have had limited success with only 11% of conservation agriculture (CA) adoption globally (Kassam et al. 2015). In the United States (U.S.) and Europe, where CA adoption is highest, soil erosion rates continue to be much greater than the sustainable replacement rate of soil (Pimentel 2006). Though limited soil disturbance (no-till) remains a requirement for sustainable agriculture, a yield benefit to no-till is not clear (Pittelkow 2015). Despite the growing use of cover crops in the U.S. (30% per year from 2010-2013) (CTIC 2014), an obvious economic benefit has not been established and their adoption is partially related to government subsidies (UCS 2013). Many states in the U.S. Mississippi River drainage basin have implemented nutrient reduction strategies to address issues with excess reactive N and P in the environment (EPA 2016); however, over application of N and P occurred in 70% and 46% of reporting U.S. watersheds, respectively (IPNI 2012). The 2015 Gulf of Mexico dead zone resulting from nitrate (NO_3^-) was above the five-year average (NOAA 2015a) and the occurrence of harmful algal blooms in connection with P may be on the rise (NOAA 2015b).

If the benefits of CA practices are clearly evident, why are humans reluctant to adopt them? The answer may be in "The Tragedy of the Commons" (TOTC) (Hardin 1968). The TOTC represents situations where open access resources (i.e. commons) exist and have finite abundance (e.g. fish, animals, wood, and drinking and irrigation water). If resource ownership is shared, individuals have an inherent incentive to maximize their exploitation of the resource since the benefit is solely theirs and the cost is shared by all users of the resource. This behavior pattern repeats until the resource is irreparably degraded and all users suffer catastrophically. Hardin lays out a blueprint solution through two choices users have to save the commons: privatization of the resource or regulation of the resource. Ostrom et al. (1994) go further by categorizing regulation of the resource as government regulation through laws or self-regulation through agreements. A driver of agricultural change cited in Hazell and Wood (2008) is the presence of adequate property rights (i.e. privatization). In areas where farmers have substantial property rights, they have a long-term perspective in managing their privately held resources (the soil) and can better employ CA with the expectation of a return on their investment. This is plainly seen in the U.S. where non-farming landowners now own 80% of farmland (USDA 2015). In crop farming, privatization of soil has been made possible through western property rights, but this is improbable with common resources like water and air. Inextricably linking the quality of resources such as soil, water, and air (NRC 1993, 2003; IPCC 2014b) has been a major accomplishment, but educating the public about these connections is a large feat due to their complexity. Given the connection of soil quality to water and air quality, it may be possible to compel land managers to improve the quality of common resources like water and air by proxy since they are the sole proprietor of their soil. In areas with highly erodible soils, conservation tillage or even perennial farming (e.g. pasture or tree plantation) has been popular, though through the help of government programs. However, in regions where the economic benefit to conserving soil is not clear because of gentle slopes or very deep soils (e.g. U.S. Midwestern prairie and Pacific Northwest Palouse) some type of regulation may be the only alternative.

The TOTC concept has been used widely as an example regarding resource *depletion* in zero-sum economic game theory and in several instances as a teaching tool (FTE 2008, 2010; Barnett 2016; Learn Liberty 2016; Mitchel 2016; Sterman et al 2016). Hardin (1968) notes the TOTC can be applied to resource *pollution* and it has been used in few examples of agricultural pollution and nutrient management (Good and Beatty 2011; Stavi and Lal 2013). Furthermore, Ostrom et al. (1994) define a common-pool resource (CPR) as having (1) difficulty of excluding individuals from benefitting from the resource and 2) subtractability of the benefits consumed by one individual from those available to others. Therefore pollution via excess nutrients, pesticides, sediment, etc. in air and water fits the TOTC model. A broad-based decision support tool was developed as a way to teach users about the complexity of nitrogen pollution and policy solutions (Erisman 2002). However, in this example, only one player represents "farming" therefore no communication or coalitions between the multiple farmers can materialize. An agricultural based game was developed with similar goals (Wittgren et al. 2005); however, it was reported to be expensive to play and specific to Swedish agriculture.

The objectives of this work are to build a game that (1) is widely accessible and applicable (2) engages individuals in the problems facing sustainable food production (3) educates individuals about technical solutions to achieve sustainable food production and (4) raises awareness to the social impediments to those solutions.

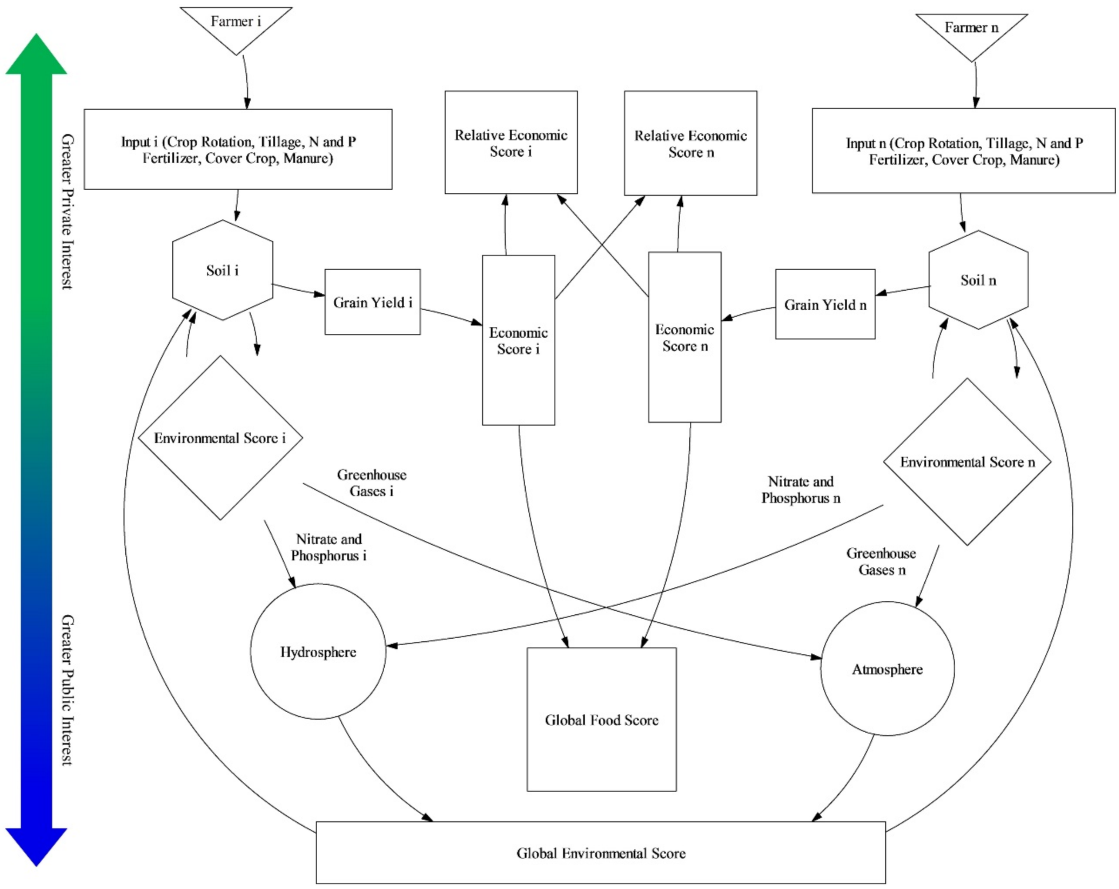

Figure 1. EQCom game elements and factors influencing cropping system related environmental quality in the commons.

Methods

EQCom (Environmental Quality in the Commons) is a simulation game based on the TOTC. The "commons" in this game are the hydrosphere and atmosphere. EQCom is similar in game theory to the "Prisoner's Dilemma" (PD) where a rational player repeatedly defects out of self-interest. The major difference between EQCOM and PD is that EQCom players can communicate and form coalitions to work toward long-term sustainability and common interest. Figure 1 summarizes broad game elements and Table 1 summarizes farmer decisions and outcomes. The accumulation of all farmer decisions are used to calculate relative economic score, global environmental score, and global food supply score. A low relative economic score causes individual farmer failure, a low global environmental score causes declines in yield and impacts to air and water. A low global food supply score causes food shortage and system collapse. Impacts to air and water come from *The Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC 2014a**)** and *Water Quality for Ecosystem and Human Health* (Carr and Neary 2008), respectively.

Table 1. EQCom farmer decisions and outcomes that effect private interests (soil quality, crop yield, and production cost – economic score) and public interests (water and air quality – environmental score).

Management Decision	Choices	Economic Score	Environmental Score
Crop Rotation	Yes, No	0, 1	1, 0
Tillage	Conservation, Full	0, 1	1, 0
Nitrogen Rate	Conservative, Aggressive	0, 1	1, 0
Nitrogen Timing	Spring, Fall	0, 1	1, 0
Nitrogen Placement	Sub-surface, Surface	0, 1	1, 0
Phosphorus Rate	Soil Test Based, Single rate	0, 1	1, 0
Phosphorus Timing	Spring, Fall	0, 1	1, 0
Phosphorus Placement	Sub-surface, Surface	0, 1	1, 0
Manure Rate	P-Based, N-Based	0, 1	1, 0
Manure Timing	Spring/Summer, Fall/Winter	0, 1	1, 0
Manure Placement	Sub-surface, Surface	0, 1	1, 0
Cover Crop	Yes, No	0, 1	1, 0

Results
Outcomes in EQCom include degradation or remediation to the atmosphere and hydrosphere. Aesthetic and economic value to weather, ecosystems, drinking water, agriculture resiliency, industry, recreation, energy production, and fishing may be affected. Positive outcomes require cooperation with other players and a long-term vision. Efforts to achieve maximum short-term profit result in negative consequences. To optimize EQCom as a tool for increase global nutrient use efficiency and conservation farming, the game will be tested on farmers, students and researchers. Additionally, the potential impact of playing this educational game include a deeper understanding amongst students, farmers, and policy makers of (1) the problems facing sustainable food production, (2) the technical solutions required to achieve sustainable food production and (3) and the social impediments to those solutions. It is important to note that while EQCom simulation outcomes are based on established scientific research, its outcomes will not represent every agro-environment or management scenario, and thus its outcomes should be used as a guide rather than a prediction.

Conclusion
EQCom is potentially applicable and will be accessible as an educational tool globally. The goal for this game is to be easy, exciting, interesting and understandable to students, farmers, and policy makers. While some actual players may be opposed to government regulation, this game may compel farmers to adopt self-regulatory systems through soil and water conservation organizations already in place.

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