Spring 2021

Developing Blockchain Exercise using PEWI: Analyzing Blockchain Use in Agricultural Supply Chain

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MASTER OF SCIENCE IN INFORMATION SYSTEMS

MIS 599 – Creative Component/Research Paper

Advisory Committee:
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ACKNOWLEDGEMENTS

I would like to take this opportunity to express my gratitude to those who have helped me with various aspects of my creative component. First and foremost, Dr. Lisa Schulte Moore for giving me an opportunity to be a part of the PEWI project, the LESEM lab and an extended member of the NREM department. She has been a strong pillar of support throughout my master's degree at Iowa State University. Without her guidance and encouragement, I would not have been able to participate in the various opportunities outside of my discipline area.

I would also like to thank Dr. Nancy Grudens-Schuck for her insight and guidance and also for pushing me to produce better work. Her kindness and support made my work pleasant and extremely enjoyable. She also supported me to participate in numerous conferences and presentations in my relatively short time as a graduate student.

Finally, I would like to express my gratitude towards my advisor Dr. Anthony Townsend for his valuable suggestions, encouragement and insight.

The PEWI Blockchain exercise project has been funded by the National Science Foundation Award: 1924178.

Abstract

People in Ecosystem Watershed Integration (PEWI) is an opens source web-based game developed to help people learn about multifunctional agriculture and human landscape interactions. PEWI allows users to change land uses across a 6000-acre watershed and instantly observe how changes to the agricultural land cover affect the ecosystem service indicators. The interactive watershed in the game is designed as 593 grid cells and is accompanied with nine maps to help users in the strategic placement of land uses. The current version of the PEWI simulation game comprises of four ecosystem service modules – Habitat, Soil Quality, Water Quality and Yield. Blockchain is considered one of the most disruptive technologies that allows the development of decentralized systems. Its application has been most prominent in the form of digital currencies (e.g. Bitcoin, Ethereum etc.) and smart contracts. While blockchain application has primarily been focused on financial transactions, its unique features that supports the development of robust systems without the need for central authorities makes application potential wide ranging. Supply chain and logistic systems is one area where blockchain provides many advantages including transparent, auditable and immutable systems that hold sensitive data. The agricultural supply chain is like any other supply chain and has a great potential for the application of emerging technologies such as internet of things (IoT), cloud computing and Blockchain. This paper aims to investigate the application of blockchain in agricultural supply chain systems and develop conceptual exercises that will be included as a supplement to the proposed "Blockchain module" in the future versions of PEWI.

Introduction

People in Ecosystem Watershed Integration (PEWI) is an open source web-based simulation that helps people understand the effects of different agricultural land uses on ecosystems services. The PEWI game has been characterized as Digital Game Based Learning unit and has been and has been evaluated for its fit to two national education standards – the Next Generation Science Standards (NGSS) and the Agriculture, Food, and Natural Resources Standards (AFNR) (Anderson et al.,2020). PEWI was developed out of a need for educational units that help students to learn about relationships between science and engineering practices and land-use choices, including contemporary agricultural practices such as conservation ("no till") corn, bioenergy crops, and pasture options. At present, there are few tools for the classroom that combine DGBL with multiple ecosystem services and display instantaneous results based on user interactivity (Chennault et al. 2020). PEWI facilitates the simulation of land use and visualization and calculation of land use outcomes on an interactive watershed that is based on two Iowa landform regions, the Des Moines Lobe and the Southern Iowa Drift Plain (Prior, 1991). PEWI is designed as a visual interface that includes a watershed area, 15 land use options, seven weather conditions, five predefined physical feature maps, and three environmental service maps. Instructors can turn the features on and off.

Design

The simulation is designed as 593 grid cells configured around a vector-graphic stream that results in a 2,383 ha (5,886 ac) watershed (Chennault et al., 2020). PEWI provides nine maps that include topographic relief, flood frequency, strategic wetlands, sub-watershed boundaries, drainage class, and soil class to help the student to make strategic land use selections. PEWI calculates the results for 16 ecosystem service outcomes and presents the results in the form of a numerical table that includes appropriate unit measures for each indicator. Users are provided with 15 land use options in the game to meet their agricultural goals.

Results in PEWI are presented in the form of interactive charts as well as in the form of tables.

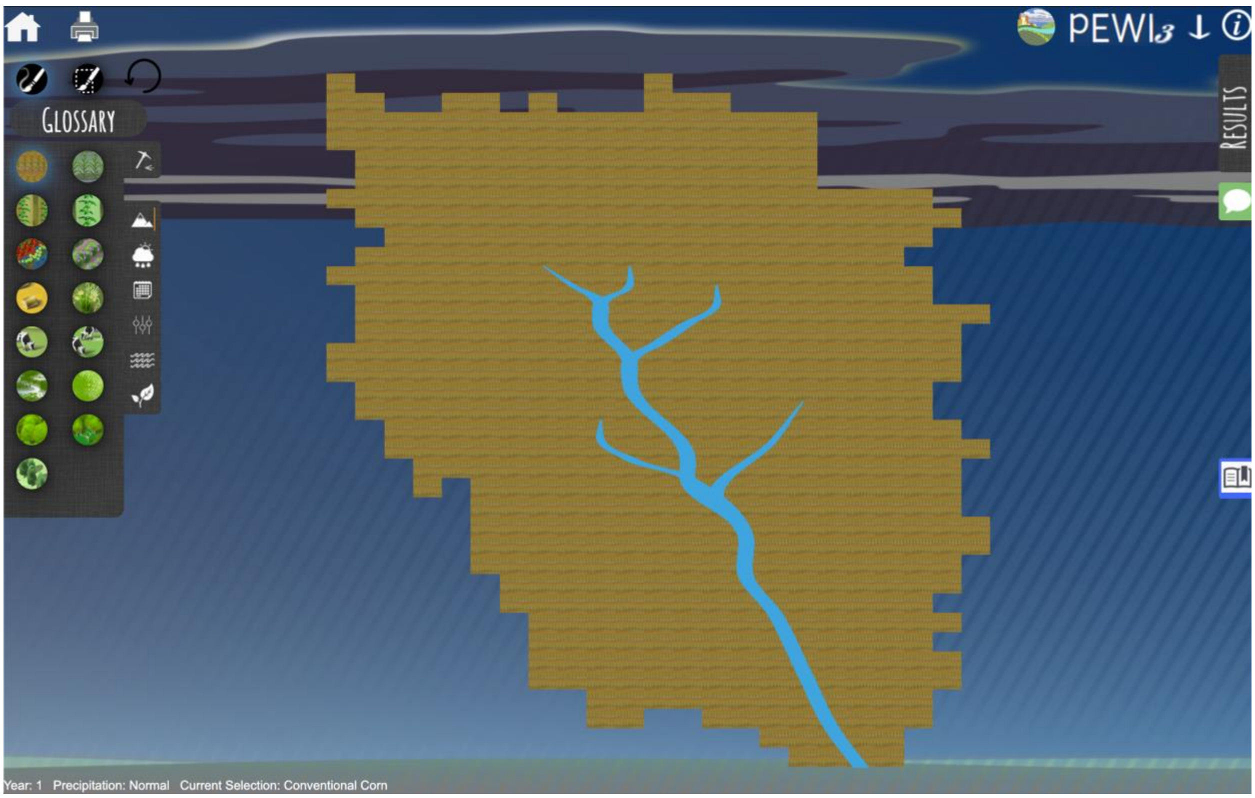


Figure 1 Screenshot of the default PEWI landscape

Figure 2 PEWI's 15 Land Use Options

Gameplay

PEWI starts with conventional corn as the base land use across the whole watershed. Users can play with an open goal to see the effects of each land use option on the ecosystem service indicator results or can have strategic goals. For example, users can aim to improve biodiversity across the watershed. The default watershed landscape comprising of only conventional corn starts with a biodiversity score of 0 out 100. Users can use a different land use either across the whole watershed or in select areas as per their choice. The game has two land use applicators – a broad applicator to apply land uses across a group of cells across the watershed in one action, and a select applicator to apply land uses in select cells of the watershed. Each land use affects the ecosystem services and PEWI's ecosystem model calculates results instantaneously. Multiple land uses can be applied in the game based on the user's need to make "tradeoffs" to achieve their goals.

Results

The PEWI model generates instantaneous results – users can click the "Results" tab to view results in two tabs. The model calculates results for three years producing indexed score for 16 ecosystem indicators. The scores are presented in Metric and English units. The first tab showcases the results in an interactive chart format. The charts can be toggled to sort results based on years, land uses and crop categories (annual grain, annual legume etc.). The second tab displays the results in the form of a table that contains results for all 16 ecosystems service indicators.

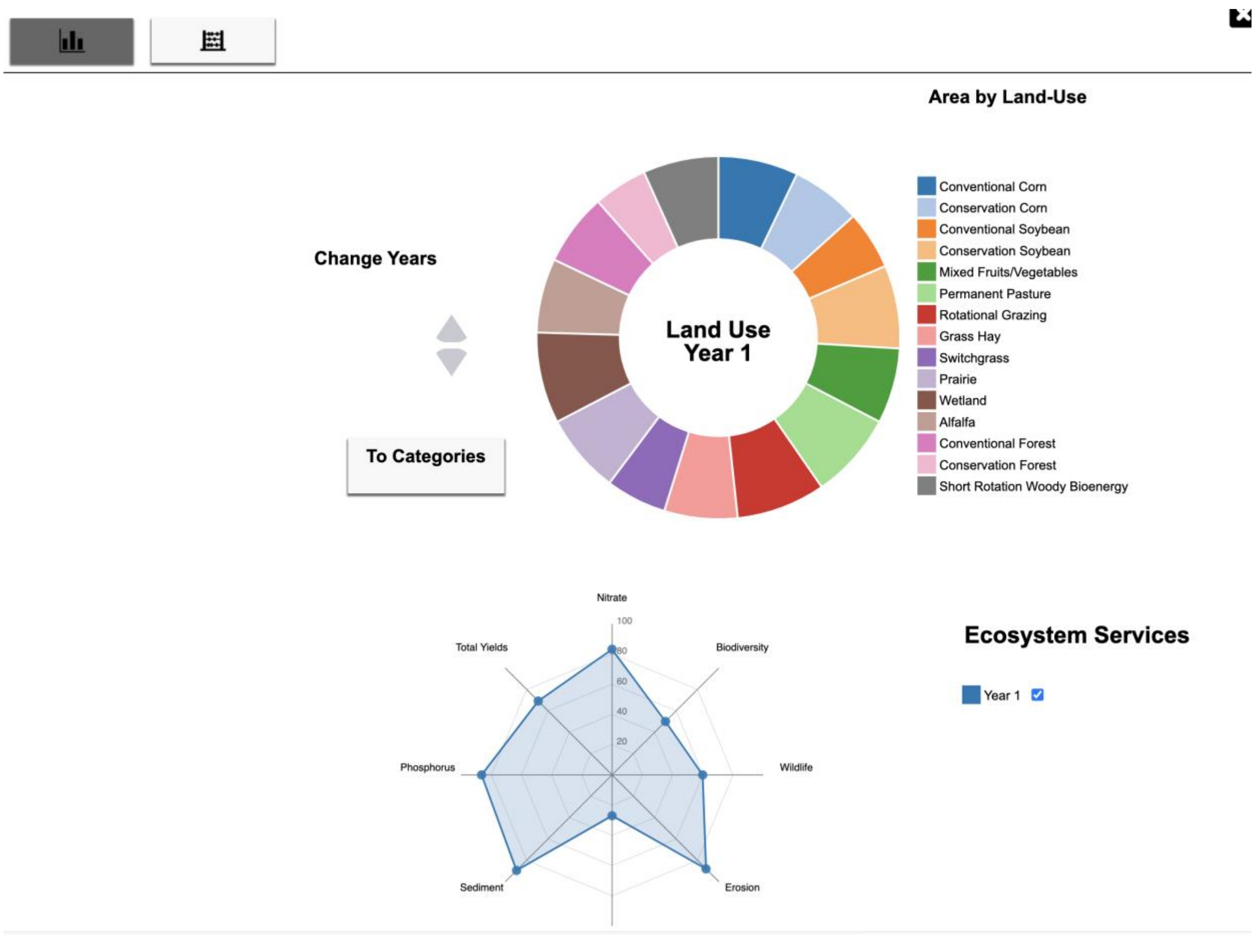


Figure 3 Screenshot of Results Tab 1

Land Use Category	Y1	Percentage	Y1	Units (English)	Y1	Units (Metric)
Annual Grain						
Conventional Corn Area	7.1	percent	417.3	acres	168.9	hectares
Conservation Corn Area	6.2	percent	365.8	acres	148	hectares
Annual Legume						
Conventional Soybean Area	5.2	percent	309	acres	125.1	hectares
Conservation Soybean Area	7.4	percent	436.3	acres	176.5	hectares
Mixed Fruits and Vegetables						
Mixed Fruits and Vegetables Area	6.7	percent	395.5	acres	160.1	hectares
Pasture						
Permanent Pasture Area	7.7	percent	456.3	acres	184.6	hectares
Rotational Grazing Area	7.9	percent	467.8	acres	189.3	hectares
Perennial Herbaceous (non-pasture)						
Grass Hay Area	6.5	percent	380	acres	153.8	hectares
Switchgrass Area	5.4	percent	319.5	acres	129.3	hectares
Prairie Area	7.1	percent	418	acres	169.2	hectares
Wetland Area	8.1	percent	477.3	acres	193.1	hectares
Perennial Legume						
Alfalfa Area	6.6	percent	388.8	acres	157.3	hectares
Perennial Wooded						
Conventional Forest Area	6.4	percent	379.5	acres	153.6	hectares
Conservation Forest Area	4.8	percent	283	acres	114.5	hectares
Short Rotation Woody Bioenergy Area	6.7	percent	395	acres	159.9	hectares

Ecosystem Service Indicator / Measurement	Y1	Score	Y1	Units (English)	Y1	Units (Metric)
Habitat						
Game Wildlife	60	(out of 100)	6	pts	6	pts
Biodiversity	50	(out of 100)	5	pts	5	pts
Soil Quality						
Carbon Sequestration	27	(out of 100)	3329.4	tons	3020.4	Mg
Erosion Control / Gross Erosion	88	(out of 100)	14707.8	tons	13342.7	Mg
Water Quality						

Figure 4 Screenshot of Results Tab 2

Ecosystem Service Indicator / Measurement	Y1	Score	Y1	Units (English)	Y1	Units (Metric)
Habitat						
Game Wildlife	60	(out of 100)	6	pts	6	pts
Biodiversity	50	(out of 100)	5	pts	5	pts
Soil Quality						
Carbon Sequestration	27	(out of 100)	3329.4	tons	3020.4	Mg
Erosion Control / Gross Erosion	88	(out of 100)	14707.8	tons	13342.7	Mg
Water Quality						
Nitrate Pollution Control / In-Stream Concentration	83.1	(out of 100)	6.6	ppm	6.6	mg/L
Phosphorus Pollution Control / In-Stream Loading	86.4	(out of 100)	1.8	tons	1.6	Mg
Sediment Control / In-Stream Delivery	89.4	(out of 100)	2474.9	tons	2245.2	Mg
Yield						
Corn Grain	13.3	(out of 100)	160149.8	bu	4067.8	Mg
Soybeans	12.9	(out of 100)	45037.5	bu	1225	Mg
Mixed Fruits and Vegetables	6.6	(out of 100)	1736.6	tons	1575.5	Mg
Cattle	12.7	(out of 100)	617.6	animals	617.6	animals
Alfalfa Hay	6.6	(out of 100)	2084.7	tons	1891.2	Mg
Grass Hay	6.3	(out of 100)	2008	tons	1821.6	Mg
Switchgrass Biomass	5.4	(out of 100)	790.5	tons	717.1	Mg
Wood	8.6	(out of 100)	92386	board-ft	218	m^3
Short Rotation Woody Biomass	1.1	(out of 100)	3947	tons	3580.7	Mg

Figure 5 Screenshot of Ecosystem Service Indicator Results

Review of Literature

Over the recent years we have seen the emergence of blockchain technology and its use in many areas of business. It has most widely been popular because of its use in finance – decentralized currencies (cryptocurrency), self-executing digital contracts (smart contracts) and real-time transaction systems. The invention of blockchain technology was first successfully explored in the form of Bitcoin – a peer-to-peer network-based cryptocurrency allowing financial transactions to take place without the need of a central authority (Tschorsch & Scheuermann, 2016).

Blockchain works as a distributed data structure that consists of nodes that participate in a peer-to-peer to validate each transaction on the network. The benefits of using such a system of decentralized information storage in various practices is slowly being analyzed and put into practice. As blockchain is an emerging subject field in supply chain it has been found to apply in several supply chain scenarios as seen in the Wang et. al (2019) study. Wang et al. (2019) analyzed the current understanding of blockchain systems and their application in supply chain systems.

1. Drivers of blockchain in supply chain systems

1.1 Trust

Wang et. al (2018) found that trust has been seen as a key driver influencing the adoption of blockchain based supply chain systems. In supply chain, trust refers to data integrity of information that is provided by the actors or participants in a transaction. Such trust is generated from a “shared source of truth” (Michelman et al., 2017). This is where blockchain provides a crucial function by providing a seamless network that conveys a shared source of truth to generate trust among trade partners and supply chain actors. Since, blockchain by design depends on multiple stakeholders to approve each transaction, the presence of such a system within a supply chain allows “stakeholders to transact with one another without requiring an intermediary” (Wang et al. 2018, p. 12) or centralized authority. The lack of a central authority is beneficial for increasing the speed of transactions and increases reliability between partners. An important application of blockchain is within the food supply chain to ensure foot safety due to growing concerns among consumers. Abeyratne and Monfared (2016, p. 2) found that “Sustainability standards and certifications such as Fairtrade, or Organic have become important tools that support conscientious consumption by providing consumers with a better understanding of the product life cycle”. For example, a meat subscription box sold by Grass Roots Farmers’ Cooperative uses blockchain technology; consumers are able to locate the raising conditions of the animals in their subscription box. (Grass Roots Farmers’ Cooperative 2017, Kamalaris et. al., 2019).

1.2 Auditability

Another driver of blockchain deployment is audatability (Wang et al., 2019). The blockchain is a tamper proof data record that is auditable and self-regulating without the need of a central authority. Since the blockchain provides a decentralized database structure, it is tamper-proof and inherently maintains an audit trail by design. All transactions taking place on the blockchain are either public for public blockchains or private for permissioned blockchains and hence make the process trustworthy and ensure data integrity (Wang et al., 2019). A well-known example of a public blockchain is Bitcoin along with most other cryptocurrencies such as Ethereum, Ripple etc. The distributed ledger for cryptocurrencies like Bitcoin are available for the public and anyone is able to participate in the network (Brody, 2019).

Importantly, implementation of blockchain technology can help in identifying fake and illegal products that were previously being passed through the supply chains due to corruption and irregularities in the systems.

1.3 Immutability

In a blockchain, the data is distributed across different computers known as nodes and is not collected at one central point. Once a block is added to the blockchain it cannot be changed or tampered and hence it makes the data immutable (Kamilaris et. al., 2019). Immutability enables an audit trail across the nodes and a block that has been added to the blockchain cannot be changed as it will not be accepted by all the nodes in the network. This makes the data in the blockchain less susceptible to cyber-attacks and almost makes it impossible to being forged or manipulated (Wang et. al., 2019).

1.4 Provenance

Blockchain technology offers better supply chain provenance. Deploying blockchain creates a unique fingerprint for each product in the supply chain with which it can be traced to its origins or to any individual stage throughout the chain (Wang et. al., 2019). The unique fingerprint is the form of a digital token that is assigned to a product at each stage in the supply chain and is constantly updated or reassigned in the blockchain as the product moves from one stakeholder to the next within that supply chain. (Kamble et. al., 2019).

1.5 Risk Management

Every business faces a risk due to delay of payments, data security and improper asset management. With the application of a distributed database and self-executing smart contracts these risks can be mitigated. For example, smart contracts which are a part of the blockchain model allow instantaneous payments based on product location data and dealing stakeholders do not have wait for trade settlements (Wang et al. 2019).

1.6 Traceability and Transparency

Blockchain technology provides traceability through inherent design. Each block can be traced by its timestamp and any information can be retrieved from the block to be audited. In a permissioned blockchain, all member nodes are allowed to trace any information in a block across the whole blockchain allowing real-time audits. This capability brings data transparency in the network as nodes can raise concerns based on data inspection. Since, the database is distributed and the same data is available to all nodes at the same time, any concern regarding data integrity are quickly resolved (Kamble et al., 2019).

1.7 Reduced transaction costs

Blockchain technology usage leads to a reduction in transactions costs (Kamble et. al., 2019). It offers "cryptographic signature protection and removes the need for intermediaries to validate transactions leading to reduced transactions costs" (Kamble et. al., 2019). The stakeholders are held accountable in a blockchain network due to smart contracts and maintain consensus on each transaction because of shared availability of trusted data present in each block.

2. Value proposition for the agriculture supply chain

Blockchain technology brings in transparency, traceability and auditability in supply chain systems by allowing the nodes (participants in a permissioned blockchain) to validate each transaction. Each product and its movement through the systems is recorded in a block creating a digital record from production to its sale (Patel et al., 2017). The presence of several intermediaries causes a disconnect between the market demand and the agricultural supply from the producers (Taylor et al., 2009). There is disconnect between agriculture production and the market demand due to the presence of several intermediaries in the supply chain between producers and consumers. Agricultural production is prone to high risk because of this disconnect and would benefit from controlling risks and improve a balance and transparency of information between producers and consumers. Enabling blockchain systems would better mitigate the risks and generate trust among market participants (Kamble et al., 2018). Blockchain in the agricultural supply chain will also help in certifying food quality, safety and sustainability of food products. Abeyratne and Monfared. (2016) provide examples of data types that can be present in agricultural supply chain that can help improve data integrity and build trust among producers and consumers. These include sensor-based timestamps, location data (collected from Radio Frequency Identification (RFID) tags), product specific data (attributes, quantity etc.), as well as environmental impact data (CO_2 emissions, energy consumption etc.). Pilot programs have shown that crucial supply chains such as pharmaceutical products and food have an immense potential to integrate blockchain technology and show positive results. These supply chains need to have systems in place for reliability, traceability and product provenance. McKenzie (2018) showed that a Walmart pilot program demonstrated that blockchain enabled tracking of sliced mangoes from US stores to their source in Mexico takes only 2.2 seconds for each traced package. Previously it used to take approximately seven days to track the same package.

The recent rise in Internet of Things (IoT) devices and their proven use in different supply chain systems has enabled promising innovation in the Agriculture and Food supply chain systems as well. The present IoT based Agri-Food supply chain systems follow a centralized infrastructure which leaves room for error in traceability and data reliability (Caro et al. 2018). Caro et al. (2018) demonstrate that new systems like AgriBlockIoT provide solutions to the existing problems through a fully decentralized blockchain based system.

The proposed blockchain-based agriculture systems break down in four actors:

1. Producers: Farmers responsible for actions such as seeding, planting and harvesting.
2. Processing: This actor performs actions such packaging, and distribution.
3. Retailer: This actor is responsible for taking the products from the processor and representing it to the final consumer through retail stores.
4. Consumer (Final Stage): This is the final stage of the chain where the actor procures the final product from the retailer.

A *farm-to-fork* approach in these blockchain based systems would allow the final actor (consumer) to access important information about each product and trace relevant data all the way to the first stage (producer). These systems would leverage IoT based sensors at each stage such as IoT based weight scales, smart-tags to add key information about the product at each stage provide end-to-end traceability to the consumer.

Motivation for PEWI Blockchain Exercise

As noted in the sections above there is a significant need for Blockchain-based Agri-Food supply chain systems. Many such system innovations are already taking place and require some amount of education and training to justify the need for such systems to their users.

The PEWI game provides an opportunity for high-school and college level students to understand the impacts of land uses on the ecosystem through result measurements provided for various ecosystem indicators.

The Blockchain exercises will aim to augment the understanding of users on the subject of Blockchain as well as the benefits of blockchain-based systems that leverage results from ecosystem service indicators in tools like PEWI to provide the final stage actors i.e., the consumers in the blockchain with an end-to-end view of the environmental impacts of the agriculture / food products they consume.

Conventional Corn, Conservation Corn, Conventional Soybean, Conservation Soybean, Mixed-Fruits and Vegetables which are land uses in PEWI have a considerable impact on ecosystems services from production to the retail stage in the supply chain. The PEWI Blockchain exercises will use the results from PEWI that are a part of the production stage to provide students with a birds-eye view of how blockchain can help them in analyzing this impact.

PEWI Blockchain Exercise 1

The PEWI blockchain exercise is a simple exercise aimed at helping students learn the benefits of using blockchain in an agricultural supply chain using the PEWI game while focusing on making strategic land use decisions in the PEWI game.

This exercise can be completed either individually by each student or in teams.

Prerequisites

Students will be expected to be familiarized with the PEWI game interface. Students will be asked to access the results tab in PEWI and note results from the results table.

Overall Learning Goals

Students will use the PEWI's Results Tab to learn how each land use affects the ecosystems service indicators. In this exercise students will only act as validators / consumers for each transaction on the Blockchain. The benefits of having results from ecosystem services within the hands of the consumer will be explained to students through this exercise to aid in the understanding of blockchain. This exercise will aim to simplify the blockchain systems at a bird-eye-view. The blockchain allows the "consumer" to verify environmental benefits offered by the final products. To understand how each stage works and how transactions are added to the blockchain we recommend the PEWI Blockchain Exercise 2.

Learning Goals

By the end of this activity learners will be able to:

1. Understand benefits of incorporating blockchain technology as part of a field-to-market supply chain systems.
2. Report results from the PEWI results tab and understand how these results affect the last stage of the blockchain i.e., the consumer stage.

Following the activity learners should be encouraged to engage in a discussion regarding:

1. Blockchain-enabled food supply chain systems.
2. Consumer's willingness to pay higher prices food prices and farmers.
3. Suppliers engaging in sustainable practices.

Technology Notes

- Students and educators can refer to the PEWI Teachers Guide for detailed instructions and lessons plans for the PEWI game.
- Display screen using a projector for students to follow along.
- We recommend 1:1personal laptop or computer to student ration; and an internet connection.
- Exercise handouts will be provided to students for participation in the activity.

Part 1:

Basics of Blockchain

1. **Distributed Ledger**

The blockchain is a distributed ledger that can record various types of transactions (financial, contracts, inventory etc.). The distributed ledger is available to all stakeholders in the network and make each transaction (block) auditable.

2. **Block**

Each block in the blockchain represents a transaction. For a block to be added to the blockchain it has to meet certain conditions. Once it meets the conditions and is verified as a valid block it is added to the blockchain. Once a block is added to the blockchain it is immutable i.e. the transaction cannot be changed or altered. An important to point to note is that the conditions that make a block valid are different from the data being recorded and stored in each block.

3. **Network, Nodes and Miners**

A blockchain is maintained as peer-to-peer network. The network is a collection of nodes that are interconnected to each other. The node which can be individual computers store the entire ledger. Miners process and validate each node.

Blockchain in Food Supply Chain

A blockchain in food supply chain will act as a distributed ledger for each transaction at each stage of the supply chain. Each block will record data that is considered valuable at each step and once a block is validated it is added to the blockchain.

Our simplified food supply chain blockchain model will have four stages:

5. Producers (Farmers):
   Information about the crops (corn), pesticides used, fertilizers used, information about the farm and farming practices involved will be recorded in the block.
6. Processing:
   Information about the farm, the factory and its equipment, the processing and distribution methods used will be recorded as part of this block.
7. Retailer:
   Detailed information about each food item, its quantity, time on the shelfs etc. are stored as part of the block.
8. Consumer (Final Stage):
   This stage of the supply chain does not add to the blockchain but rather consumes the data stored in the blockchain. The consumers can use an internet enabled device (smartphone, laptop etc.) to check all the information associated with the food item from the producer stage to the retailer stage.

Part 2:

For this exercise the students only act on the Final Stage of the blockchain. The students will use PEWI results to view transactions that are added to the blockchain and engage in discussion pertaining to the need of this information for the consumers and how it would affect consumer behavior.

1. Students can use multiple land uses for this exercise. The first step would be to focus on two or three ecosystem indicators for this exercise. The Blockchain module would allow for selective ecosystems service indicators to be used for analysis. For example, students can focus only on the validating Biodiversity, Erosion Control and Nitrate Pollution Control results.
2. With the above step in place each land use that is added in PEWI will affect the selected indicator values.
3. These values will be recorded at each change or addition to land-use as a block and would become a part of the overall blockchain. The addition of blocks and their verification will be simulated automatically as part of the PEWI game for the purposes of this exercise.
4. These blocks will then be reported in the final transaction table containing all blocks on the blockchain (Figure 1).

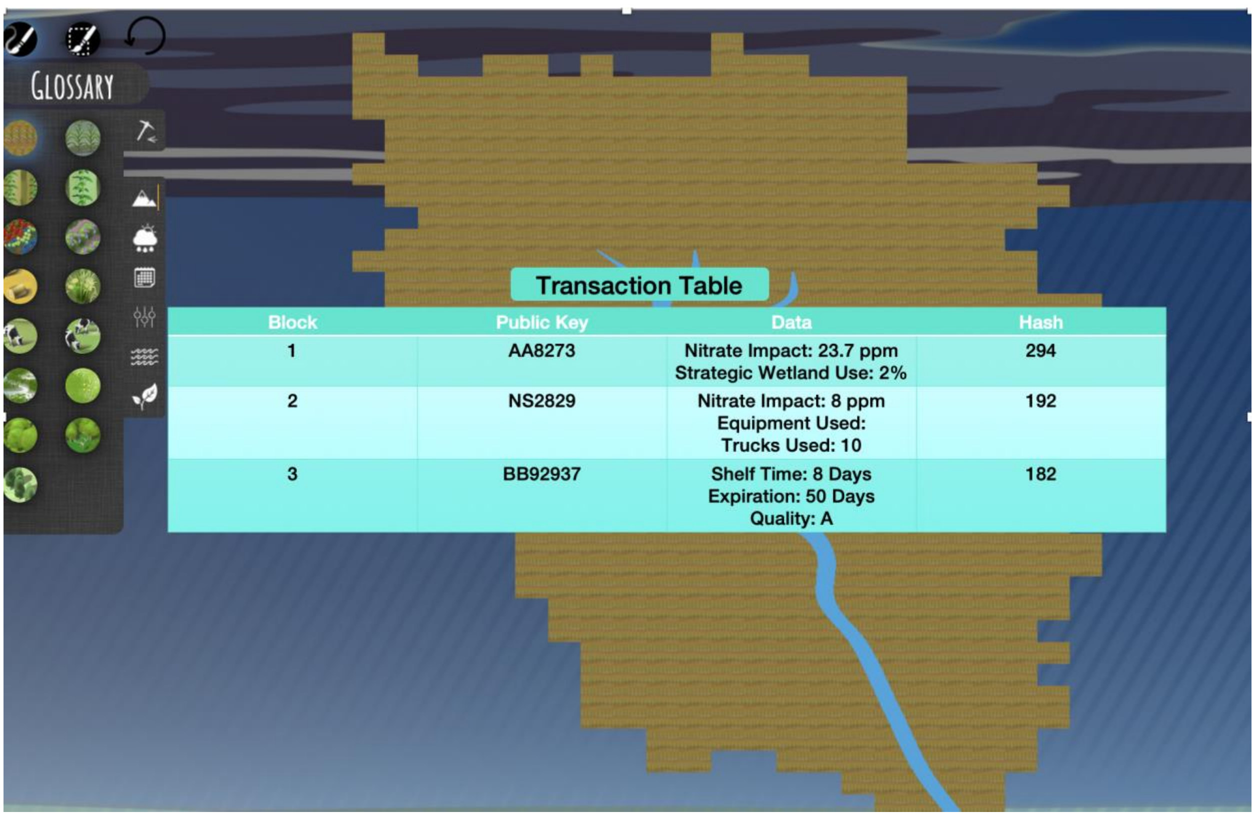


Figure 1: Transaction Table

5. After completing the above steps students will now discuss the impact of each stage of land use addition/change based on the transactions table produced by PEWI's Blockchain module. This discussion should help students in understanding consumer behavior based on environment impacts from each land use.
6. The discussions around the transactions table should guide students on answering questions such as:
    a. If you use more of a certain land use in strategic places on the PEWI watershed you have a greater Biodiversity score, will you choose a final food product as a consumer that has a greater Biodiversity score versus another with a lesser score?
    b. Would a consumer choose a product with greater yield efficiency – essentially making it cheaper, over a product that has a lower overall yield but less harmful impact on certain ecosystems service indicators?

PEWI Blockchain Exercise 2

The PEWI blockchain exercise is an advanced exercise aimed at helping students learn the fundamentals of blockchain and the benefits of using blockchain in an agricultural supply chain using the PEWI game.

This exercise requires a minimum of 3 students. If there are more than 3 students, they can be divided into 3 groups each of which act as a participating authority certifying "blocks" in the blockchain.

Prerequisites

Students will be expected to be familiarized with the PEWI game interface. Students will be asked to access the results tab in PEWI and note results from the results table.

Overall Learning Goals

Students will use PEWI's multiplayer feature to learn how each transaction is added as a block in the agricultural supply chain. The blockchain allows the "consumer" to verify environmental benefits offered by the final products. For this activity, we will only use Conventional Corn as the commodity in the supply chain.

Learning Goals

By the end of this activity learners will be able to:

3. Understand the benefits of a distributed ledger system.
4. Understand the append-only ledger.
    a. Each ledger entry is linked to the previous entry.
    b. Each ledger entry is immutable once added to the ledger.
5. Understand benefits of incorporating blockchain technology as part of a field-to-market supply chain systems.
6. Report results from the blockchain system created during the exercise.

Following the activity learners should be encouraged to engage in a discussion regarding:

4. Blockchain-enabled food supply chain systems.
5. Consumer's willingness to pay higher prices food prices and farmers.
6. Suppliers engaging in sustainable practices.

Technology Notes

- Students and educators can refer to the PEWI Teachers Guide for detailed instructions and lessons plans for the PEWI game.
- Display screen using a projector for students to follow along.
- We recommend 1:1personal laptop or computer to student ration; and an internet connection.
- Exercise handouts will be provided to students for participation in the activity.

Part 1: Understanding the Blockchain (Optional Exercise)

This part of the exercise is optional. This part explains the basics of a blockchain and how each block is approved and added to the blockchain.

Basics of Blockchain

2. **Distributed Ledger**

The blockchain is a distributed ledger that can record various types of transactions (financial, contracts, inventory etc.). The distributed ledger is available to all stakeholders in the network and make each transaction (block) auditable.

2. **Block**

Each block in the blockchain represents a transaction. For a block to be added to the blockchain it has to meet certain conditions. Once it meets the conditions and is verified as a valid block it is added to the blockchain. Once a block is added to the blockchain it is immutable i.e. the transaction cannot be changed or altered. An important to point to note is that the conditions that make a block valid are different from the data being recorded and stored in each block.

3. **Network, Nodes and Miners**

A blockchain is maintained as peer-to-peer network. The network is a collection of nodes that are interconnected to each other. The node which can be individual computers store the entire ledger. Miners process and validate each node.

Blockchain in Food Supply Chain

A blockchain in food supply chain will act as a distributed ledger for each transaction at each stage of the supply chain. Each block will record data that is considered valuable at each step and once a block is validated it is added to the blockchain.

Our simplified food supply chain blockchain model will have four stages:

9. Producers (Farmers):
   Information about the crops (corn), pesticides used, fertilizers used, information about the farm and farming practices involved will be recorded in the block.
10. Processing:
    Information about the farm, the factory and its equipment, the processing and distribution methods used will be recorded as part of this block.
11. Retailer:
    Detailed information about each food item, its quantity, time on the shelfs etc. are stored as part of the block.
12. Consumer (Final Stage):
    This stage of the supply chain does not add to the blockchain but rather consumes the data stored in the blockchain. The consumers can use an internet enabled device (smartphone, laptop etc.) to check all the information associated with the food item from the producer stage to the retailer stage.

Steps:

- For this step we will use the Optional Handout and the Miner Worksheet.
- Students will be divided into 3 groups of miners.
- Miners will calculate hash for each block by solving an equation.
- The miner that calculates the hash first will raise their hand; other miners will vote on the validity of the hash.
- If the hash is deemed valid by more than 50% of the miners, the block will be added to the blockchain

Hash Equation

Hash = a + b + c – Last two digits of previous hash

- a = value of letter assigned to stage (A: Producer, B: Processing, C: Retailer)
- b = value of first letter of public key
- c = value of letter of data type

Once students complete calculating each block hash, we will ask "add" the block to the blockchain. When all the blocks are added the students will play the role of consumers. Consumers can verify contents of each block but cannot mutate the data in the blockchain.

After completing the above steps, students should be encouraged to discuss the benefits of the blockchain particularly to raise awareness about the environmental characteristics of the food produced. A blockchain incorporated within the food supply chain will allow consumers to easily see data about the soil, water where the food is produced and also note the ecosystem indicators such as land degradation, impacts to biodiversity and wildlife.

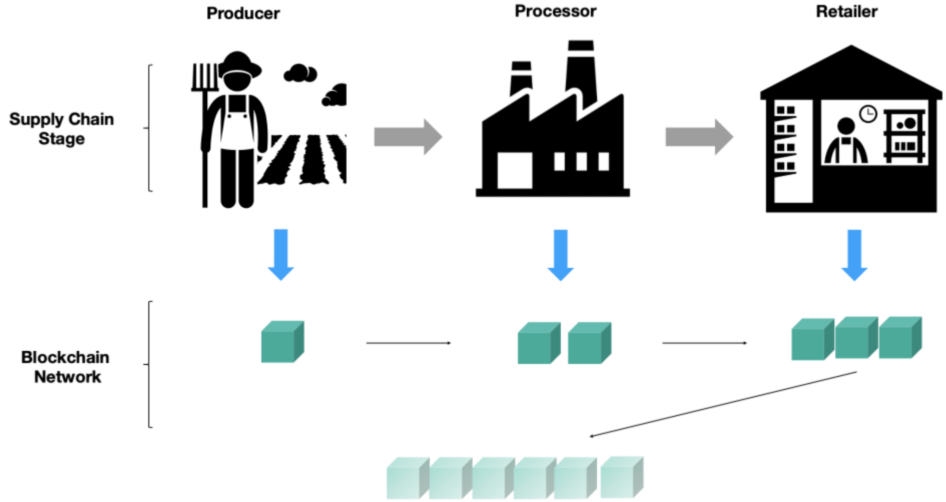


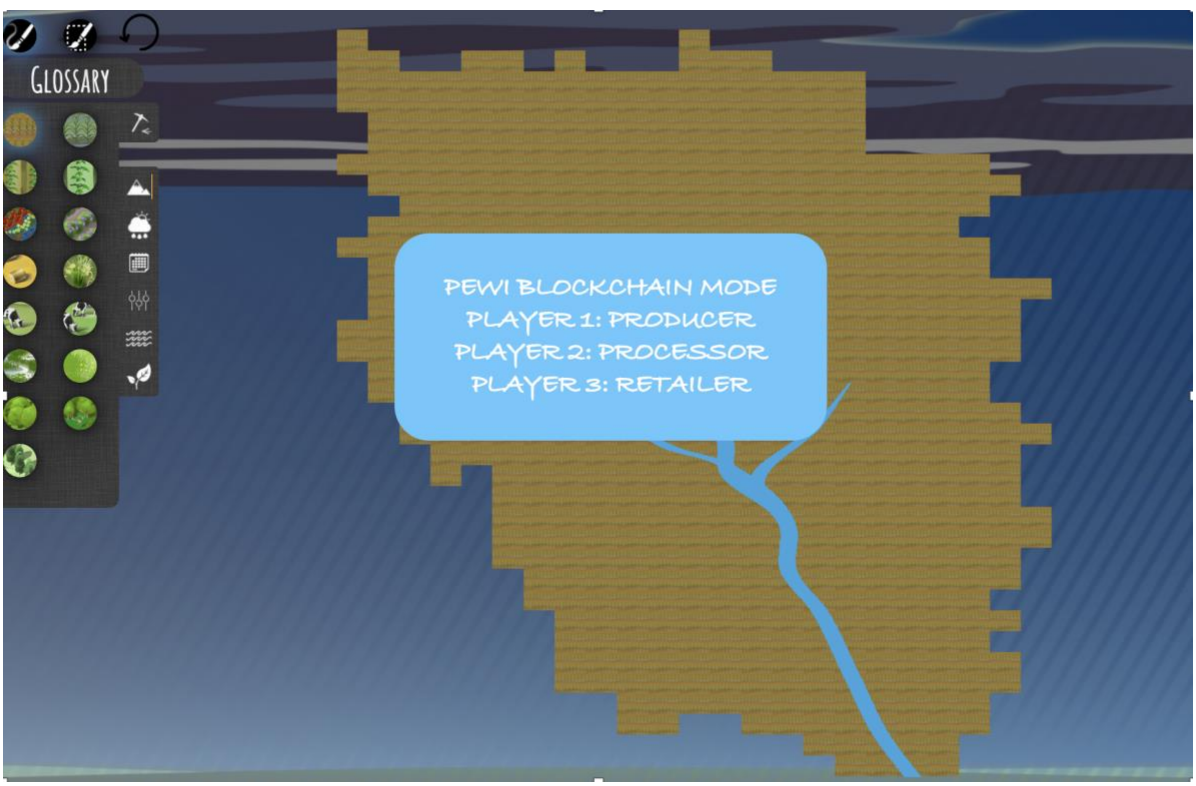
Figure 1 Simplified Blockchain-Enabled Food Supply Chain Network

Part 2: Blockchain with PEWI

This part uses the PEWI blockchain module. The PEWI blockchain module divides players into three teams each corresponding to a specific stage of the blockchain-enabled food supply chain.

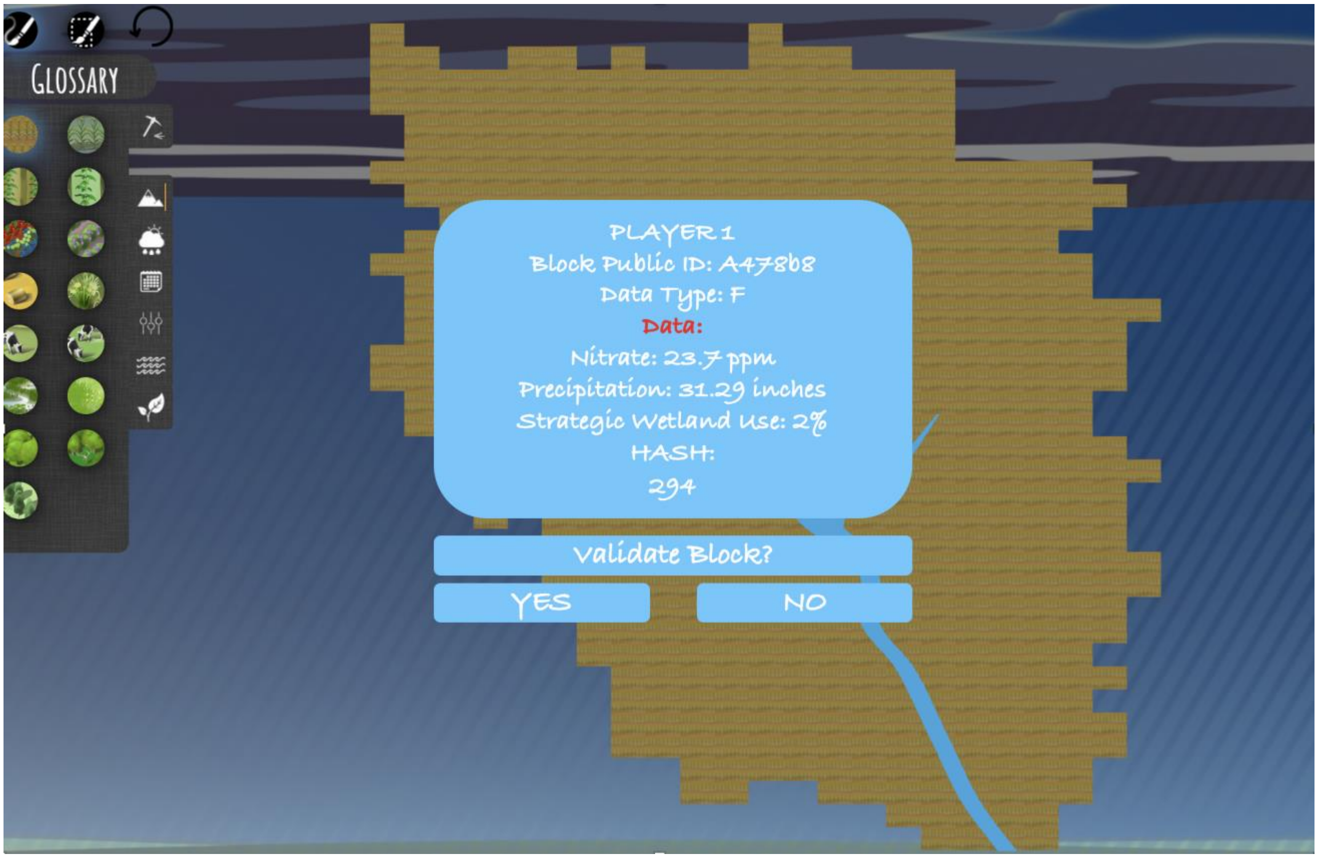
Our simplified food supply chain blockchain model will have three stages
(Repeated from Part 1):

1. Producers (Farmers):
   Information about the crops (corn), pesticides used, fertilizers used, information about the farm and farming practices involved will be recorded in the block.
2. Processing:
   Information about the farm, the factory and its equipment, the processing and distribution methods used will be recorded as part of this block.
3. Retailer:
   Detailed information about each food item, its quantity, time on the shelfs etc. are stored as part of the block.



Steps:

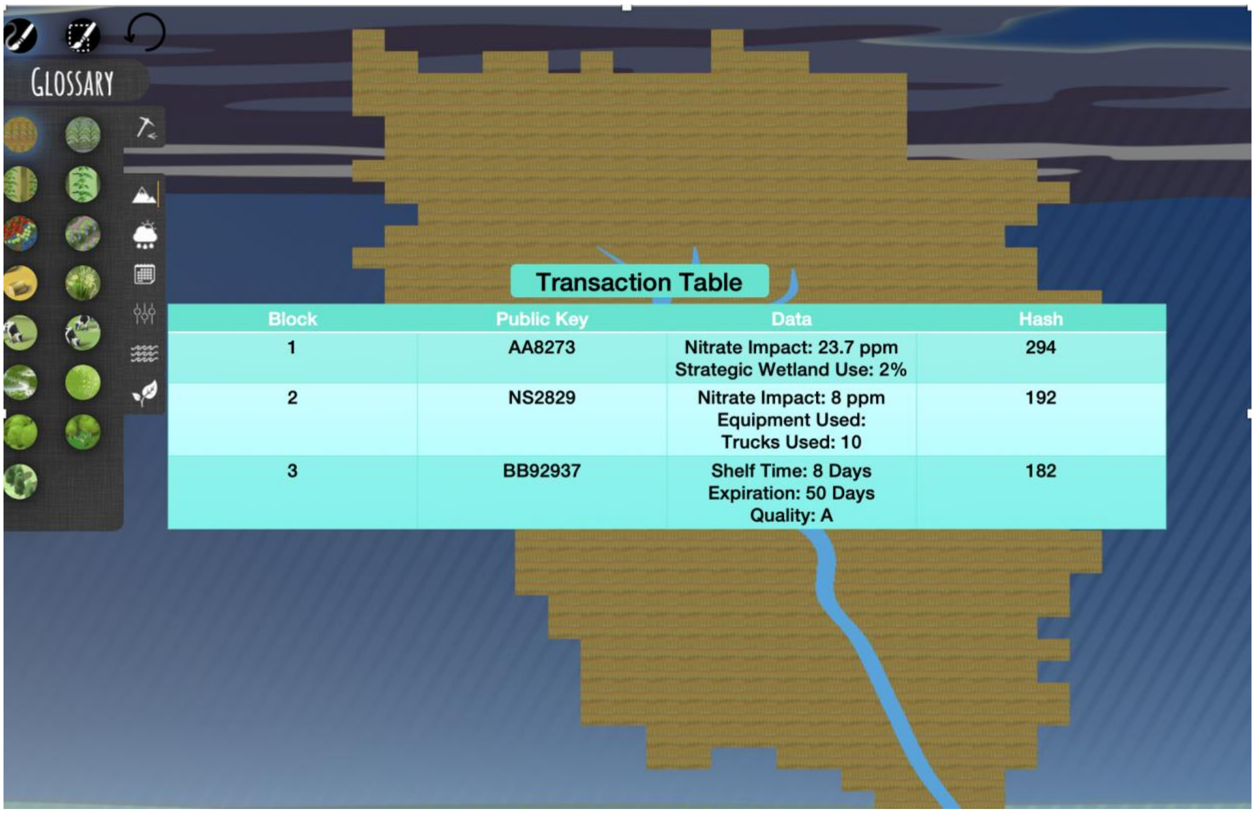
1. The blockchain mode of PEWI divides players into three teams.
2. Each team supplies transaction data to a block. Students can retrieve this data from the results tab in PEWI.
3. Once the data is entered, an automatic public key is generated for the block.
4. The player then asks for their block to be validated. The block can be validated by the other players or third-party nodes (PEWI simulated).
5. Once the block is validated, players get a confirmation that the block has been added to the blockchain.
6. Once all blocks are added to the blockchain, the transaction table is generated in PEWI that displays all transactions for that food item / land use and the data associated with each transaction.



Example Block 1 for the Producer Stage

Discussion

Students should discuss the results in the transaction table noting the change in the ecosystem service indicator values at each stage in the blockchain. For each indicator values are aggregated by adding values from the previous stage. The students playing the role of the consumers can then note the environmental impacts of a food item and argue the potential for improvements in the supply chain.



Block	Public Key	Data	Hash
1	AA8273	Nitrate Impact: 23.7 ppm Strategic Wetland Use: 2%	294
2	NS2829	Nitrate Impact: 8 ppm Equipment Used: Trucks Used: 10	192
3	BB92937	Shelf Time: 8 Days Expiration: 50 Days Quality: A	182

Optional Exercise Handout

Table of Letter Values

Letter	**Value**	**Letter**	**Value**
A	**32**	**N**	**45**
B	**33**	**O**	**46**
C	**34**	**P**	**47**
D	**35**	**Q**	**48**
E	**36**	**R**	**49**
F	**37**	**S**	**50**
G	**38**	**T**	**51**
H	**39**	**U**	**52**
I	**40**	**V**	**53**
J	**41**	**W**	**54**
K	**42**	**X**	**55**
L	**43**	**Y**	**56**
M	**44**	**Z**	**57**

Block 1:

Stage	Public Key	Data	Hash
(A)Producer	A478b8	Data Type: F Pesticides Used: Fertilizers Used: Farming Practices:	For example: 212

Block 2:

Stage	Public Key	Data	Hash
(B)Processing	H289v2	Data Type: P Factory Equipment Used: Electricity Source: Distribution Truck types:	

Block 3:

Stage	Public Key	Data	Hash
(C)Retailer	N729m3	Data Type: R Foot item: Quantity: Expiration Date: Shelf time:	

Miner Worksheet

Block	a	b	c	Last Two Digits of Previous Hash	= Hash
1					
2					
3					

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