|  |  |
| --- | --- |
| **Title** | **Investigating Economic Impact of Genetic Modification in the Timber Industry [A Calculations-Based Lesson]** |
| **Introduction** | This lesson is designed to get students to look at the economic impacts of genetic modification from perspectives of the forester, the timber company, and a wood energy plant that would use the wastes from the timber company to produce energy. Using random number generators or dice, students will have to determine the relative values of cost and efficiency with regard to the trees used in the industry. Students will get practice with calculations in order to determine the economic ‘value’ of implementing GM technology, and how that can potentially ripple through the industry. Students will also evaluate the process to see, in their specific situation, the relative economic impact of the GM modification costs and resulting benefits. |
| **Curriculum Alignment** | AP Environmental Science-  Competency Goal 7: The learner will build an understanding of environmental decision making.  Objective 7.02 Analyze cultural and ethical considerations regarding the environment; Environmental worldviews; Sustainable development.  NC Essential Standards  Bio.3.3.3- Evaluate some of the ethical issues surrounding the use of DNA technology (including cloning, genetically modified organisms, stem cell research, and Human Genome Project). |
| **Learning Outcomes** | During the activity: Students will work with concepts of: costs of GM technology, relative % efficiency of various processes within the timber industry, the processes involved in commercial forestry, the timber industry, and wood energy using timber processing wastes. Students demonstrate thinking during the activity as they evaluate, at the conclusion of each phase, how the GM technology has affected their business.  End of Activity: Following the activity, students should be able to evaluate the relative impact of GM technology throughout the entire process of GM forestry through the timber waste in the wood energy plant. Students should see [and be able to explain that] that:   1. The general economic impact of GM technology is highest at the source, where the forester invests in the technology, and therefore has the highest economic investment. 2. The general difference should lessen throughout the process. 3. Students are then able to assess the situation by looking at the individual steps and benefits of each step.    1. Changes later in the process have less of an impact generally because they are in effect for a shorter part of the process. |
| **Time Required and Location** | Approximately 80 minutes [100 minutes with extension]  10 minutes introduction  10 minutes general explanation of process  25 minutes calculations and worksheet  15 minutes discussion questions in small groups  20 minutes present to class [this may be eliminated depending on time available- students may write out answers to turn in instead] |
| **Materials Needed** | Handouts of calculations worksheets  Technology with random number generators [dice are alternative if the technology is unavailable]  **Technology resources**   * Personal electronic devices [smartphones] with random number generator applications [alternative: computers with internet access to access [www.random.org](http://www.random.org)]. Students are working independently, but up to three students can share one device if needed, provided that they generate unique random numbers for each person. |
| **Participant Prior Knowledge** | Students should have covered topics such as:  \*What is GM technology?  \* How can trees be genetically modified?  \* Basic processes of timber production and wood energy production  A simple question/answer session at the beginning of the lesson can accomplish this, ensuring that students are familiar with the processes.  Examples of questions:   1. What does it mean if something is genetically modified?   *The genes have been altered*   1. How does ‘engineering’ fit into the GM process?   *High tech genetic engineering processes alter plants at the genetic level instead of relying solely on an improvement process*   1. How can trees be genetically modified? Look for at least three options.   *Possible answers include: increased resistance to pests, increased pesticide resistance, disease resistance, faster growth, lignin or cellulose content in cell walls, tolerance for different climates, etc*   1. What is the general process of timber production?   *Trees come into plant and have bark removed; cut into boards; treated; waste is carried away*   1. What is the general process of a biomass wood energy plant?   *Timber company waste comes into plant and is incinerated to produce heat; turbine generator model; waste from incineration is disposed of in landfill* |
| **Facilitator Preparations** | One aspect of this lesson involves the use of random number generators that can be found as free apps on smartphones [Android, Apple] and other technology devices. Teachers should examine their school/system policy regarding the student use or personal electronic devices during class, as some school systems do not allow this use. If use is not automatically allowed, teachers should check with administration to see if students can complete an acceptable use policy for these personal electronic devices. The day before [or two] direct students to either the Apple AppStore or the Android Market for a free “Random Number Generator” app. There are many available for free. The website [www.random.org](http://www.random.org) is also an option for a random number generator. Dice can be used if the technology is not available.  Teachers should make copies of the worksheets needed and make sure that students have access to the number generators. |
| **Activities** | Exploration: Students use random number generators to see how a small change can end up making a big difference.  As individuals: You are given a bank account with $100,000 in it by a rich uncle that you didn’t know existed. The same uncle has agreed to increase the amount in that account in five years to an amount based on a calculation. You get to choose a random number between 1 and 10 to fit into an unknown calculation. Using your number generator, select your number. [students select random numbers using the generators]  Show students the following equation for percentage increase.  % increase= [#] x[ 10/2#]  [ #]  Example using the number 1= % increase ={ [1] x [10/(1)] } / [1] = 10%  Example using the number 5= % increase ={ [5] x [10/(5)] } / [5] = 5%  Example using the number 10 = % increase ={ [10] x [10/(10)] } / [10] = 1%  \*Allow students the chance to ask questions about process of generating the random numbers. Teachers should familiarize themselves with the applications so that they can use them and answer process questions regarding the number generators.    Model System:   * Students complete the “Economics worksheet” using the random number generator.   + Example: Random number generated is 3, which leads to chestnut. The range for chestnut is 15,000- 50, 000. Plugged into the generator, a resulting yield of 33,650 is generated per acre, for a total of 336,500 board feet for the entire 100 acres.   + This provides for a ton of variation, which will make it difficult to score if you’re looking at every single number upon completion. Have students check in at the completion of the first box to make sure they know how to use the generator [or alternatively dice], then check in at the end of each page of the process. * Students will use the products from one step in the process as inputs for the next step of the process.   + Suggestion- when a student ‘checks in’ at the conclusion of one page, give him/her the next page. By placing these on different pages, it will be easier to view all at the same time at the end. This is written large enough so that if copies are an issue they can be printed two sheets per page and students still be able to read it. * At the end of each process, students will evaluate the difference in GM and non GM profits.   + To determine non-GM profits, students can plug their initial yield [in board feet] into the calculations to determine the changes in overall profit resulting from the GM technology. This can be done in the margins or along the bottom of each page.   + Students should see that early changes can lead to big changes in results later on, and the later decisions seem to have less overall impact in final profits because they come later in the process.   Content Wrap-up:   * Students will get together and compare their calculations and values.   + Look for ranges within just one type of modification or one type of tree. Look at where numbers seemed to differ the most, and what early changes produced the most varied end results. * Discuss what could account for the differences in their final profits.   + Market differences     - Some students may have been working in a much more profitable market. This can be akin to geographic differences [location within US or use of foreign lumber], or differences in timing.     - This is probably one of the more frustrating for the students because they feel that it has nothing to do with their actual species or modification. But it’s something that is going to vary and change over time that individual companies really have very little control over if at all.   + Processes at individual plants     - Efficiency in the different mills and plants could have led to big differences as technology could have led to more efficient cutting and resulting in less waste. This increased profits by having more product to sell and additionally having less waste for disposal.   + Species of trees and growing conditions present     - Different species had different potential ranges for yields. Some ranges were much higher than others indicating that it might have been more sensitive to changes in the environment.   + Environmental factors [disease, pests, drought, climate, etc]     - Each of the trees was modified for a specific purpose, but those factors may or may not have led to the changes in yield that were seen.   **Guided Practice**  Students will arrange themselves in small groups based on the type of tree that they were modifying. Recommended group size is 3-4 students. If there are more students in one group, it is recommended to split the group so that no group has more than 4 people in it.  Students should discuss all of the following questions in their group [questions may be adjusted in content or number due to academic level or time availability- these are merely a guide]. Near the end of discussion time [allow approximately 10-15 minutes] assign each group one question to discuss with the class as a whole.  [Recommendation- allow 10 minutes for small group discussion; combine small groups if needed to present their questions to the group]   * How did the type of tree being modified affect the outcome? * Do you think that type of tree, or type of modification, has a greater impact on the ending yield? * What are the effects of having ‘ranges’ for a variety of variables? How did this affect your overall profit? * What are the final ranges for profit within your group? Look at your data worksheets and figure out what causes the largest differences. * Are final profits more affected by variations in the beginning of the process, or the end of the process? Explain. |
| **Assessment** | Group Assessment: 3 groups total based on the three phases of the process:  Look at the process from the perspective of one of the phases. This will be a research-based assessment. Each group will turn in the following [allow several days to complete- maybe 5-10 min per day to work with groups for several days]: evaluation of entire process from the perspective of their individual step, suggestion of ways to increase profit without increasing sales costs. [this will usually be an increase in efficiency].   * What to look for: group participation, problem solving skills, accurate and plausible data and analysis. This is difficult to place a quantitative score on- would look at this from a Completed, Needs Revision, Incomplete perspective as far as scoring. Assign a score of 90-100 for Completed work, and students will need to get to the Completed stage in order to receive an actual numerical score. This will make students keep working until its right, and not trying to ‘fake it’ with regard to analysis.   Individual Assessment:  Written assessment: students select one of the steps in the process, and evaluate how, based on their tree type and selected modification, what the highest and lowest profits could be, as well as what impact the efficiencies as well as market prices have on the overall profit.   * Suggested for higher level students who are more prolific with mathematics skills. Students will turn in their work and explanations. Check for accuracy of mathematics calculations quickly [spot checking should suffice] and look for explanations of what impact efficiency makes in terms of profit. Some statements indicating that increase efficiency means less waste, fewer raw materials, and the same output would mean less to buy, less to dispose of, and the same amount of product. |
| **Critical Vocabulary** | Forestry Dictionary- Maryland Dept. of Natural Resources- <http://www.dnr.state.md.us/forests/gloss.html>  Biomass- amount of living material  Board foot- 1’x 1’x 1” piece of wood  Modification- change |
| **Modifications** | * For students in schools where technology is a factor, rolling dice can be a substitute for the random number generator. For each number on the dice, give a set value. See Supplemental Materials for a handout.   + This also works well for lower level students. * Modifications for EC and ESL students:   + Roll dice- allows for fewer possibilities and therefore a greater chance of more similar answers   + Work in small groups- suggest a group of 3- one person to roll dice or generate number, one person to calculate answer, and one person to record answer   + Split the assignment over several days- complete calculations for one phase [one page] each day for several days [allow for approximately 10 minutes per page for working in a group, or about 15 minutes per page working individually, to allow for more diverse learners to ask questions or double check work] * Modifications for gifted students-   + Gifted students should be able to complete the handouts outside of class; allow them to get started in class and then they can complete outside of class. They can discuss results in small groups the following day. * Modifications for time constraints:   Do pre-activities at the end of class one day, allow students to complete calculations at home, and discuss their results the next day at the beginning of class. |
| **Alternative Assessments** | For EC or ESL students, focus more on oral discussion. Look for verbal cues to indicate understanding.   * + Examples     - Increased efficiency will help increase the profits     - Ranges exist because market prices will change over time, and because efficiency will change based on things like environmental conditions affecting growth, plant genetics affecting wood production, etc.     - The type of tree and type of modification can make a big difference in terms of yield and final profit     - Make connections between efficiency and profit, and compare to the effect that market prices have on profit. |
| **References** | Random number generator- [www.random.org](http://www.random.org)   * Link to online random number generator   Weyerhauser- [www.weyerhaeuser.com](http://www.weyerhaeuser.com)   * Prominent lumber company in the southeast US   Craven County Wood Energy- [www.ccwe.net](http://www.ccwe.net)   * Example of a wood/ biomass energy company in NC   US Forest Service- [www.fs.fed.us](http://www.fs.fed.us)   * Homepage for the US forest service   NC Forest Service- [www.ncforestservice.gov](http://www.ncforestservice.gov)  Homepage for the NC forest service |
| **Supplemental Information** | Additional Research option-   * Students can select one of the tree types listed, and research one of the ways that it has been modified and why it has been modified. Have students try to find any data to support an increase in yield from the modification. |
| **Comments** | This reason I developed the lesson in this way was to increase the exposure to math content within environmental science. As an AP teacher, I have seen that math skills of my high school students are lacking, and have tried to work calculations and mathematics into as many facets of my curriculum as possible. The use of the random number generators has helped students gain more of an interest because they can see a larger range in the end result and see the application of useful and readily available technology to them.   * One of the most positive student reactions upon doing this with a small pilot group was discussing the variation. “I didn’t know there were so many different ways that it could turn out,” was one of the comments when faced with so many different times that the number generator was needed. “I think it’s really cool that I get to use my phone for this,” was another comment. |

***Investigating Economic Impact of Genetic Modification in the Timber Industry***

WORKSHEET

FORESTER

1. Select a random number 1-5 to determine the tree species to be grown, and then select a number from within the range in parentheses to determine your annual per acre yield {in board feet[bf]} from your property.

*Tree Species: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Annual Yield: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*board feet per acre*

*Total Yield: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_bf for 100 acres*

* 1. Poplar [10,000- 50,000]
  2. Ash [25,000- 60,000]
  3. Chestnut [15,000-50,000]
  4. Pine [40,000-65,000]
  5. Hemlock [20,000-35,000]

1. Determine the total yield for 100 acres.
2. Generate a number 1-5 to determine the type of genetic modification desired for your timber. For your designated modification, select a number within that range to be the resulting percentage increase in yield.

*Modification: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Increase in Yield: \_\_\_\_\_\_\_\_\_\_ %*

*New Yield for 100 acres: \_\_\_\_\_\_\_\_\_\_\_\_\_\_bf*

* 1. Disease resistance [10-25%]
  2. Faster growth [20-25%]
  3. Climate tolerance [15-30%]
  4. Wood quality/ density [5-15%]
  5. Composition of cell wall [5-10%]

1. The timber is sold for a range of $2-5 per board foot depending on the market. Generate a sale price [per board foot] and determine the total revenue generated. Multiply by 65% to account for a 35% deduction for operating costs and labor.

*Sale price: Yield for 100 acres: Total revenue*

*$\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = $\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x .65 = $\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Per board foot board feet for 100 acres (account for TOTAL Profit*

*operation costs)*

1. There is a cost of $500,000 upfront for the GM technology needed. Determine how long [in years] it will take your company to recover the costs. [There are several ways to work this out]

LUMBER COMPANY

1. Transfer the following information from the “FORESTER” page.

*Type of Tree Modified: Total Yield [for 100 acres]: Sale Price for Total Yield:*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_bf $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

1. The % efficiency for any plant [the amount of board feet that ultimately become lumber] is dependent on wood quality [even boards] as well as processing efficiency. This range is 50-80%. Select a % within this range, and calculate the amount of timber produced [in board feet] by your company.

*Yield from Forester: Efficiency of Lumber Mill: Yield Produced by Mill:*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bf x \_\_\_\_\_\_\_\_% = \_\_\_\_\_\_\_\_\_\_\_\_\_ bf*

1. Use your tree species below to find the range for sale prices [per board foot] of timber. Select a number within this range, and calculate the total revenue for your mill.

* Poplar [$5-8] Ash [$6-8] Pine [$3-6] Chestnut [$5-8] Hemlock [$4-8]

*Yield for Mill: Price [per bf]: Total Revenue for Mill:*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bf x $\_\_\_\_\_\_\_ = $\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

1. You are able to sell your waste [shavings, scraps, etc] to a local biomass energy plant that uses wood energy. They will purchase your waste for $15 per ton. One ton would be approximately the equivalent of 1000 bf’s worth of wood.

*100- [efficiency of mill]% = [waste]%*

*Yield from forester: %waste Amount waste convert to ton sell for revenue from waste*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ bf x \_\_\_\_\_ % = \_\_\_\_\_\_\_\_\_\_\_\_\_ bf ÷ 1000 [= \_\_\_\_\_\_\_\_\_\_\_] x $15 = $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

1. Calculate total revenue for the lumber mill, taking into account operational costs of 40%.

*lumber revenue waste revenue Total revenue %profit Amount profit*

*$ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ x 60% = $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

WOOD ENERGY PLANT

1. Transfer the following information from the “LUMBER COMPANY” page.

*Amount of waste: Total paid for waste:*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_tons $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

1. One ton of wood waste can produce 1500-2500 kwh of electricity, depending on the efficiency of the furnace and quality of wood scraps burned. Some harder woods may burn more completely or for longer due to the density of the wood. Select a number within this range and determine the total kwh produced by the plant annually.

*Amount of waste kwh produced per ton total kwh produced*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

1. The company is able to power the plant with its own energy, so operational costs are only 20% to cover labor and maintenance. This means that a portion of the energy produced is also used to operate the plant [10%]. Determine the kwh to be sold for profit, which will range from $.15-.20, depending on the market.

*Total kwh produced: % to be sold: Total kwh to be sold*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x 90% = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

1. Determine the profit of the company by determining the sales total, and then multiplying by 80% to account for the operational costs. [determine sale price per kwh using number generator]

*Total kwh to be sold price per kwh sales total % profit Total profit*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x $ \_\_\_\_\_\_ = $ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ x 80% = $ \_\_\_\_\_\_\_\_\_\_\_*

Values for Dice:

Type of Tree:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | Poplar |
| 2 | Ash |
| 3 | Chestnut |
| 4 | Pine |
| 5 | Hemlock |
| 6 | Roll again |

Poplar Yield:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 10,000 |
| 2 | 18,000 |
| 3 | 26,000 |
| 4 | 34,000 |
| 5 | 42,000 |
| 6 | 50,000 |

Ash Yield:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 25,000 |
| 2 | 32,000 |
| 3 | 39,000 |
| 4 | 46,000 |
| 5 | 53,000 |
| 6 | 60,000 |

Chestnut Yield:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 15,000 |
| 2 | 22,000 |
| 3 | 29,000 |
| 4 | 36,000 |
| 5 | 43,000 |
| 6 | 50,000 |

Pine Yield:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 40,000 |
| 2 | 45,000 |
| 3 | 50,000 |
| 4 | 55,000 |
| 5 | 60,000 |
| 6 | 65,000 |

Hemlock Yield:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 20,000 |
| 2 | 23,000 |
| 3 | 26,000 |
| 4 | 29,000 |
| 5 | 32,000 |
| 6 | 35,000 |

Type of Modification:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | Disease resistance |
| 2 | Faster growth |
| 3 | Climate tolerance |
| 4 | Wood quality/density |
| 5 | Composition of cell wall |
| 6 | Roll again |

Disease resistance %:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 10% |
| 2 | 13% |
| 3 | 16% |
| 4 | 19% |
| 5 | 22% |
| 6 | 25% |

Faster growth %:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 20% |
| 2 | 21% |
| 3 | 22% |
| 4 | 23% |
| 5 | 24% |
| 6 | 25% |

Climate tolerance %:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 15% |
| 2 | 18% |
| 3 | 21% |
| 4 | 24% |
| 5 | 27% |
| 6 | 30% |

Wood quality:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 5% |
| 2 | 7% |
| 3 | 9% |
| 4 | 11% |
| 5 | 13% |
| 6 | 15% |

Composition/Cell wall:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 5% |
| 2 | 6% |
| 3 | 7% |
| 4 | 8% |
| 5 | 9% |
| 6 | 10% |

Sale Price/board foot:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | Roll again |
| 2 | $2 |
| 3 | $3 |
| 4 | $4 |
| 5 | $5 |
| 6 | Roll again |

Efficiency of Plant:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | 50% |
| 2 | 56% |
| 3 | 62% |
| 4 | 68$ |
| 5 | 74% |
| 6 | 80% |

Price of Poplar/ Chestnut:

|  |  |
| --- | --- |
| **Value** | **Result** |
| 1 | $5.00 |
| 2 | $5.60 |
| 3 | $6.20 |
| 4 | $6.80 |
| 5 | $7.40 |
| 6 | $8.00 |