Module 1: Intro to cover crops: What is a cover crop and how do I choose which one to plant?

Key concepts: What are cover crops and how are they used to increase agricultural sustainability? What are the different services or functions that cover crops provide? How do farmers choose among the different cover crop species?

Learning Objectives:

1. Understand general and specific benefits and functions of cover crops.
2. Identify opportunities for farmers in managing and integrating cover crops into their cropping systems.
3. Apply knowledge of species specific cover crop functions to address goals in managing cropping systems.
4. Address barriers and incentives for cover crop adoption.

Components of Lesson:

1. PowerPoint lecture describing what cover crops are and the functions they provide in monoculture and mixture. Introduction to spider plots and the concept of multifunctionality.
2. Active learning in the classroom to discuss factors that cause farms to use different cover crops species. Case studies of different farms to show how farmer priorities interact with soils, environment, and rotation to impact cover crop selection and the functions provided by cover crops depicted through spider plots.

Things you will need:

1. PowerPoint, "Introduction to Cover Crops"
2. Introduction to Cover Crops - Lesson Plan
3. Case Study Activity Handouts (one for each student)

Note: ↟ in the teacher notes indicates that the following notes are for guiding the teacher and not speaking to the class.

Objectives:

1. Identify challenges faced by agriculturalists in managing soil sustainably
2. Describe the different functions of cover crop species
3. Apply knowledge of cover crop functions to address challenges of soil management.
4. Address barriers and incentives for cover crop adoption.
5. Quantify the services provided by cover crops (spider plot).

What are challenges that farmers face in managing their soil and cropping systems sustainably?

What are some potential solutions to these challenges?

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- You as the instructor will have a general understanding of the level of knowledge that the students in the class will have.

- The purpose of this initial dialogue between the teachers and the students is to quickly gauge the understanding of the students on the topic as well as to “prime the mind” of the students, to get them thinking about the bigger picture.

Image: https://www.nal.usda.gov/afsic

Learning objectives

1. Understand general and specific benefits and functions of cover crops.
2. Identify opportunities for farmers in managing and integrating cover crops into their cropping systems.
3. Apply knowledge of species specific cover crop functions to address goals in managing cropping systems.
4. Address barriers and incentives for cover crop adoption.

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↟Clarify the objectives of this module to provide a “road map” of sorts for the students.

What is a Cover Crop?

Cover crops are plants that are grown to improve the sustainability of cropping systems by providing environmental and economic benefits, such as:

- slowing erosion
- improving soil quality and fertility
- enhancing water availability
- suppressing weeds
- helping to control pests and diseases
- increasing biodiversity

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↟The slide lists several of the benefits associated with the integration of cover crops into a cropping system. Refer back to the discussion in Slide 2 regarding the challenges and potential solutions to managing farms sustainably. Many challenges to the sustainability of agriculture can be addressed through the use of cover crops.

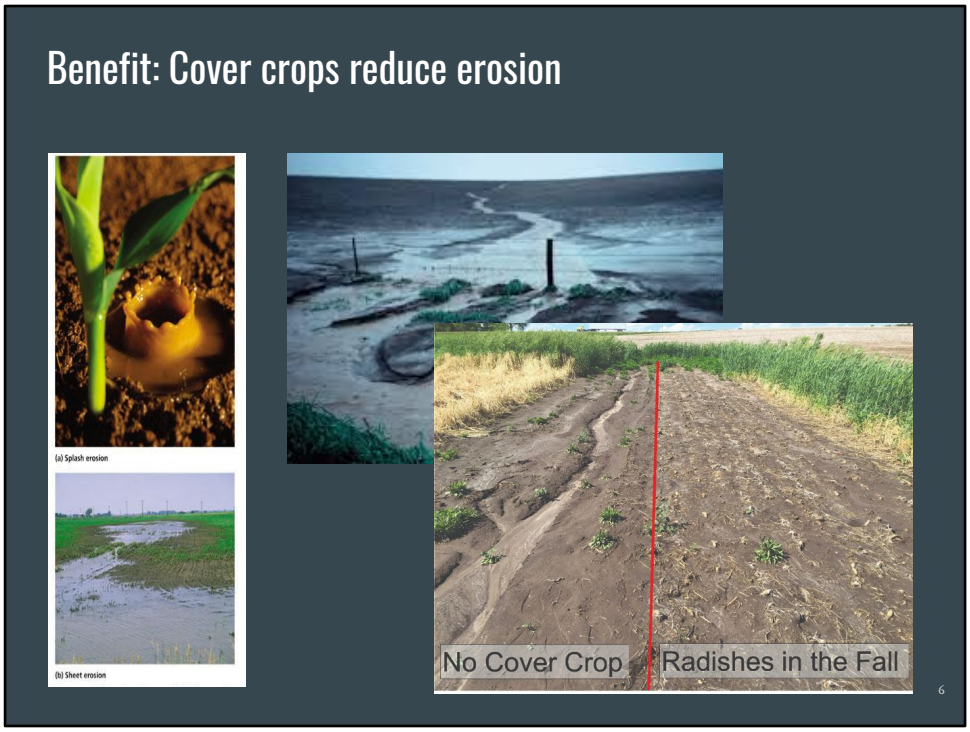
Another term that is important to know is “cash crop”, which is the crop grown primarily for harvest and sale. Cover crops are generally not harvested and sold, but instead planted for other benefits such as those listed above. In this image, the cash crop (corn) was grown and has been harvested, and a grass cover crop is currently growing and covering the ground.

Definition compiled from
https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops and
http://northeastcovercrops.com
Image from
https://www.kansasagnetwork.com/2017/cover-crop-survey-shows-return-on-investment/

This video comes from the NRDC (Natural Resource Defence Council) which can potentially a biased source of information, however it was produced really well and addresses some of the important ideas that we will address throughout this module.

↟Video duration: 3:32

↟At the conclusion of the video facilitate a discussion based on the topics raised in the video. For example:
1.) Why did this particular farmer choose to start using cover crops? (To improve soil health, cover the soil when it would otherwise be bare)
2.) What results did they find after using cover crops? (Increasing soil organic matter, protect the soil from soil erosion during heavy rains)
3.) What are some of the negative impacts on the farm and off the farm if cover crops are not used? (Soil erosion, nutrient runoff which negatively impacts water quality)
4.) Why would planting cover crops lead to reduced yields? (This will be addressed in the following module but mostly has to do with cover crops competing for resources with the cash crop as well as immobilizing Nitrogen in the soil)
5.) At 2:30 in the video the farmer states that, “we are finding that when we use cover crops in the *right way* it can actually enhance what we grow and the amount that we grow.” What do you think he means by the “right way”? This question will be the major topic for the following modules.



Bare soil is vulnerable to erosion caused by precipitation and wind. By keeping soil covered with living cover crops and/or cover crop residues, soil can be protected from loss to erosion.

↟Question to pose to class:What are the consequences of erosion and runoff? Pollution from runoff includes sediment, nutrients (especially Phosphorus which is bound to sediments), pesticides, herbicides, and harmful pathogens associated with manure. This runoff can degrade the quality of streams, rivers, and estuaries, impact aquatic life, and pose a threat to human health. The loss of topsoil and nutrients also impacts farmland productivity.

Image, top left: A) The protective “shield” over bare soil provided by a cover crop reduces the impact of rain drops on the soil surface. This helps to keep soils aggregates intact, reducing soil erosion and runoff, and increasing infiltration. B) A cover crop can slow the velocity of runoff, reducing soil loss from sheet erosion. Cover crop roots also are critical for holding soil in place.
The second image shows severe sheet erosion and the third image shows a comparison between soil that was planted with no cover crop with clear soil (rill) erosion and soil that was planted with a fall radish cover crop

The organic matter soil pool is comprised of everything that contains carbon compounds formed by living organisms. This includes dead, decomposing, and decomposed materials from plants, animals, and microbes.

Why is building organic matter in the soil important?
Organic matter impacts soil health - both the chemical and physical properties of the soil. Soil organic matter is linked to soil fertility, availability of nutrients to plants, water holding capacity, infiltration, and soil biological activity. To maintain or increase soil organic matter, we need inputs of new organic matter (anything carbon based, like plant debris, manure, compost).

Belowground: Living roots act as "carbon pumps": They exude simple carbon compounds including sugars, enzymes, organic acids, and more. These can often be directly assimilated by microbes. Additionally, carbon is added to the soil as roots die and slough off cells.
Aboveground: Soil organisms break down and decompose this added organic material, and fungi and bacteria will use energy and nutrients from the organic material to grow. The rate of decomposition is impacted by moisture, temperature, and the chemical properties of the plant/animal input material itself. Incorporating organic material into the soil through tillage will generally increase the rate of decomposition.

Benefit: Nitrogen management

- Legume cover crops can fix N from atmosphere and add to soil

- Non-legume cover crops can take up and retain N to reduce losses through leaching

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Cover crops can be used to target different nitrogen management goals. Legume cover crops, such as peas and clover, form associations with nitrogen fixing bacteria. (Nitrogen fixation involves the transformation of nitrogen gas - N2 - which cannot be taken up by plants, into a plant useable form of nitrogen.) These bacteria, Rhizobia, engage in a symbiotic relationship with legumes by providing N to the host plants in exchange for carbon from the host plants, which these bacteria use for energy and growth. Rhizobia infect the roots of legumes and form nodules (pictured).

Non-legumes such as grasses or canola (pictured) have prolific root systems that will scavenge nitrogen from the soil. These cover crops store this N in their tissues. These cover crops can be used to prevent losses of nitrogen through leaching, where water-soluble nitrate might otherwise be lost from the soil pool via rainwater or snowmelt passing through the soil into the groundwater.

(More on this later in powerpoint)

Soil can become compacted through various mechanisms, including pressure from heavy machinery, animal traffic, or loss of soil structure from tillage. Compacted soils may impact crop growth through restricted water availability and restricted root growth, can create impermeable deep soil layers that may restrict water flow, and may be less able to absorb water, increasing erosion and runoff.

Tillage radish (pictured) is known to send down a long tap root, which can penetrate compacted soil and create channels for water flow and root growth.

Tillage Radish Image from http://covercropimages.sare.org/

Benefit: Weed suppression

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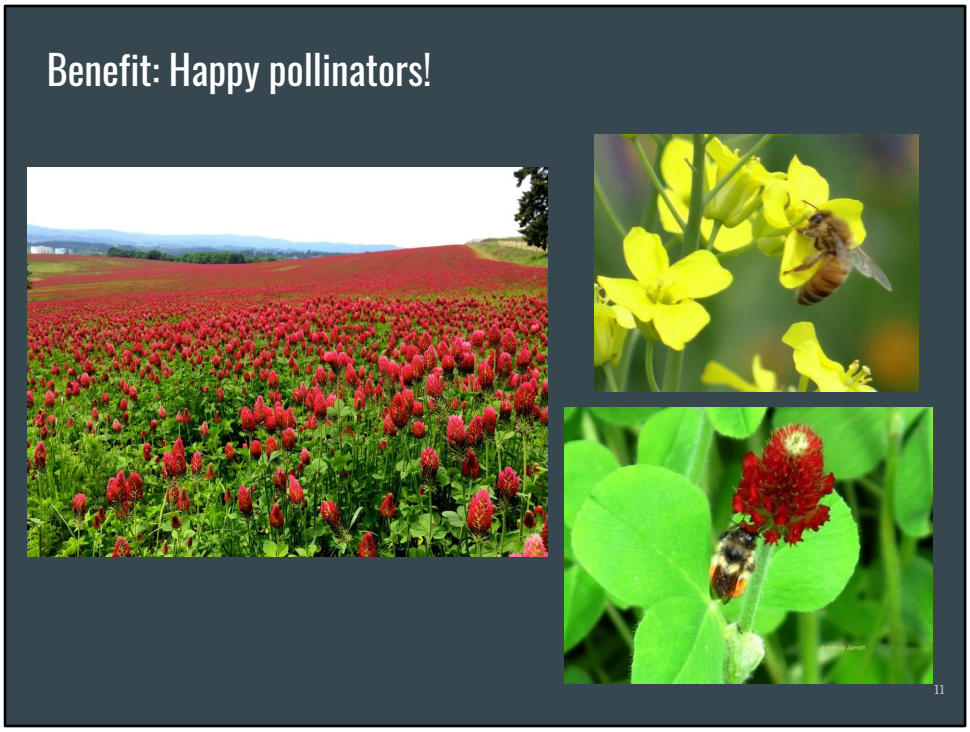
Living cover crops can reduce and suppress weeds through outcompeting them for light, water, and nutrients. A cover crop “mulch” (pictured) can also act to suppress weeds while the cash crop is growing thus reducing the need for herbicides.

Images:
http://blogs.cornell.edu/organicdairyinitiative/2015/07/22/wheres-theres-no-till-theres-a-way-organic-cover-crop-based-rotational-no-till/ ;
http://plantcovercrops.com/cover-crops-help-suppress-weeds/



Flowering cover crops will increas pollen availability and attract pollinators. Pictured above: Clover (red) and canola (yellow). Often we kill cover crops before they bloom, so if farmers want pollinator habitat they may have to plan for that by terminating the cover crop late. (But if termination is too late then the cover crop can go to seed and become a weed, so be careful)

Images from :
http://www.thelandonline.com/news/cover-crops-can-benefit-bees-farmers-bottom-line/article_be4cf79c-eacb-11e4-a0b0-83be98aa4c1b.html;
https://www.thegardenwebsite.com/covercropsandgreenmanures.html;
http://www.portlandediblegardens.com/blog/2014/10/14/growing-cover-crops-in-your-home-garden

Individual species of cover crops will have functional differences, providing a different set of benefits, or “services”.

↟ This would be a good time in the lecture for the teacher to prompt students with the title question in this slide, or some discussion to reinforce the knowledge of the different benefits of cover crops.

Plant Characteristic Examples:
Legume - N fixing
Grass - N retaining, N scavenging
Can survive winter
Dies in winter
Different chemical composition of plant tissues (carbon to nitrogen ratios)
Different root structure
Different growth rates
Different flowering times
Type of flower
Different leaf shapes, colors

Functional Differences: Legumes vs. Grasses

Legumes use N from the soil & atmosphere

- Growth not limited by soil N
- High tissue N concentration (3-4% N)
- Rapid N mineralization during decomposition
- Not very good at reducing N leaching

Grasses only use soil N

- Growth limited by soil N
- Lower tissue N concentration (1-2%)
- Possible N immobilization during decomposition
- Excellent at reducing N leaching

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Recap: Legume cover crops, such as peas and clover, form associations with nitrogen fixing bacteria. (Nitrogen fixation involves the transformation of nitrogen gas - N2 - which cannot be taken up by plants, into a plant useable form of nitrogen.) These bacteria, Rhizobia, engage in a symbiotic relationship with legumes by providing N to the host plants in exchange for carbon from the host plants, which these bacteria use for energy and growth. Rhizobia infect the roots of legumes and form nodules (pictured).

New: During decomposition of these cover crops (after either being killed by cold winter temperatures, or through mechanical or chemical termination), N will be mineralized rapidly. This means that N will be transformed from organic N in the plant tissue to plant-available N (ammonium and nitrate). This available N is now able to be used by plants, but is also now vulnerable to leaching. While the plant is growing, legumes are not a high performer in reducing N leaching both because of their ability to fix atmospheric N, and because of their root structure.

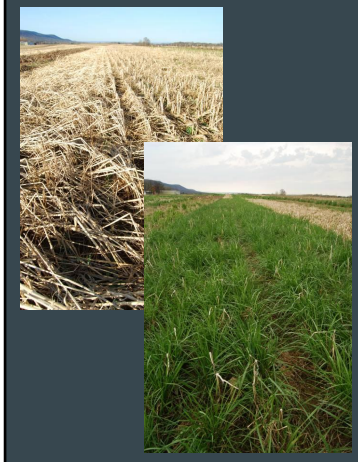
Recap: Grasses have prolific root systems that will scavenge nitrogen from the soil. These cover crops can be used to prevent losses of nitrogen through leaching, where water-soluble nitrate might otherwise be lost from the soil pool from rainwater or snowmelt passing through the soil into the groundwater.

New: During decomposition of these cover crops (after either being killed by cold

winter temperatures, or through mechanical or chemical termination), N may be immobilized. This means that N being released from the plant tissues during decomposition is taken up by soil microbes, and will not be available for plant uptake. This is a result of the high amount of carbon and relatively low amount of N in the decomposing plant tissue.

If students have already learned about the N cycle and controls on microbial mineralization and immobilization of N, this would be a good time to reinforce that knowledge by asking them to predict which cover crops will have greater net N mineralization of N during decomposition, grasses or legumes?

Functional Differences: Winter-killed vs. Winter-hardy



Winter-killed
- Rapid fall N uptake with sufficient fall growing season
- No N uptake after winterkill
- N released from decomposing residues may be vulnerable to winter and spring-time leaching

Winter-hardy
- Slower N uptake in the fall
- N uptake continues through winter and spring
- Residues decompose during growth of the next crop – significantly affecting N nutrition

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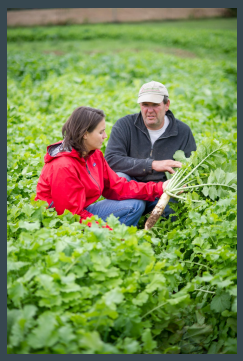
Winter-killed cover crops are killed by the cold (examples: oats, radish, fieldpea, some clovers)

- Rapid fall N uptake with sufficient fall growing season
- No N uptake after winterkill - but still may be sufficient biomass/cover to protect the soil from erosion, act as mulch for weed suppression
- N released from decomposing residues may be vulnerable to winter and spring-time leaching

Winter-hardy cover crops are able to survive the winter, sometimes above ground biomass will die back but growth will resume with warmer temperatures/more light.

- Slower N uptake in the fall (species dependent)
- N uptake continues through winter (minimal) and spring (significant)
- After termination, residues will decompose which is often during growth of the next crop – this may significantly affect N nutrition through immobilization of N by microbes during cover crop decomposition

Now we know the benefits that cover crops can provide on a farm....



...how can farmers integrate cover crops into their cropping systems?

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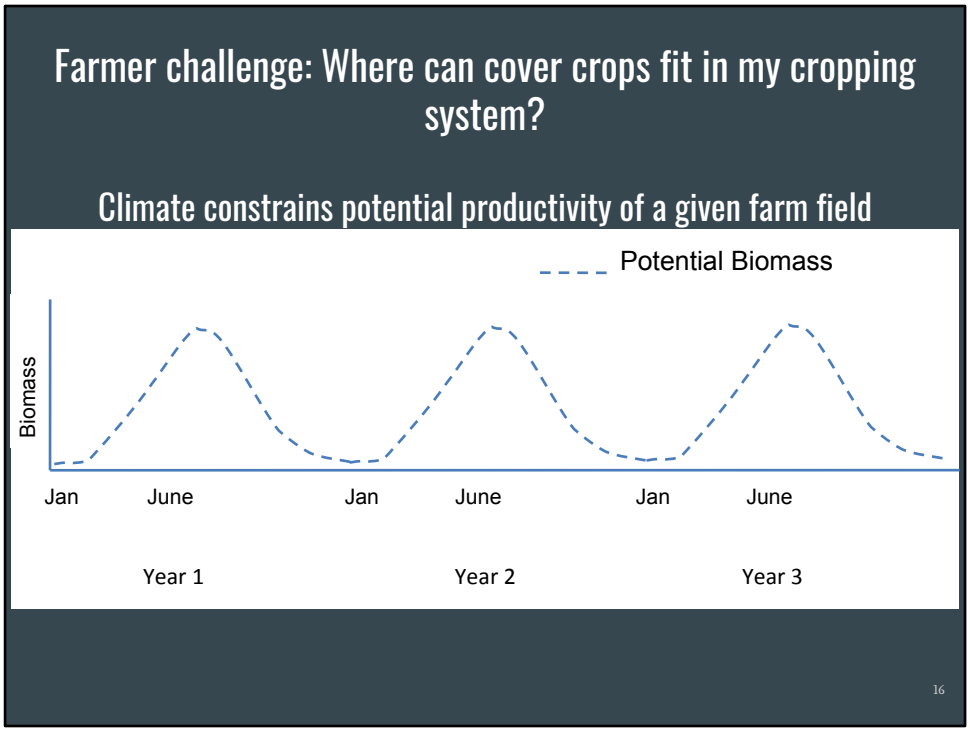
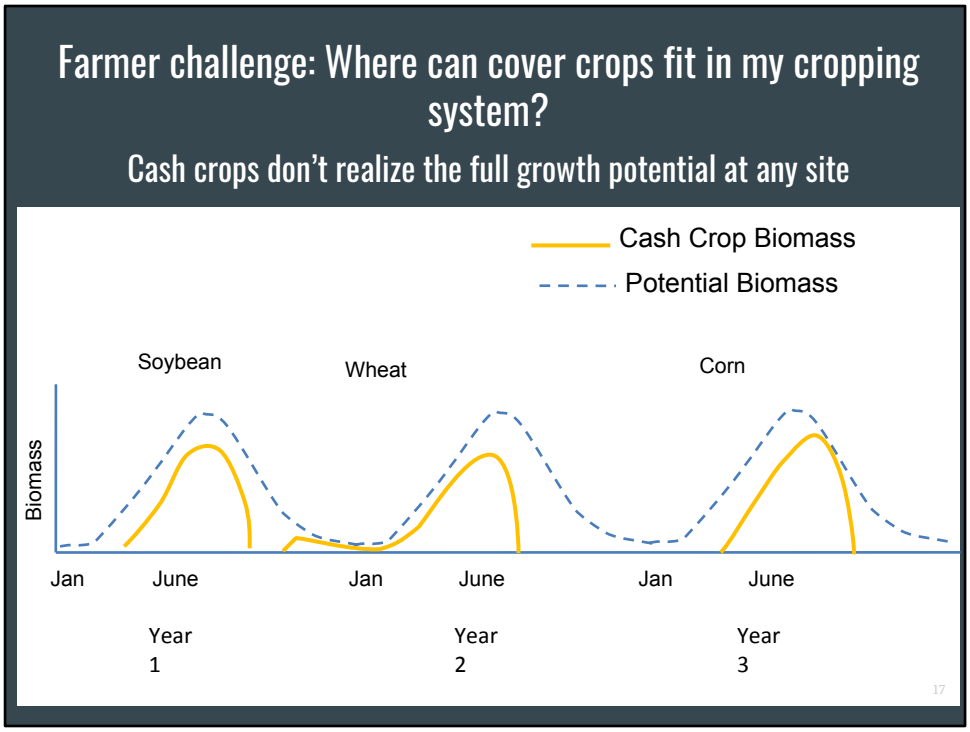
↟This is a time to recap the benefits that farmers may be targeting, how different cover crop species can be used to manage for specific functions, and also to revisit the challenges brainstormed in the beginning of the powerpoint.

↟The following slides show some graphs and charts regarding how farmers would integrate cover crops into the management of their farms. It is important that the students know how to read and interpret the graphs to understand the concepts that we are trying to explain.

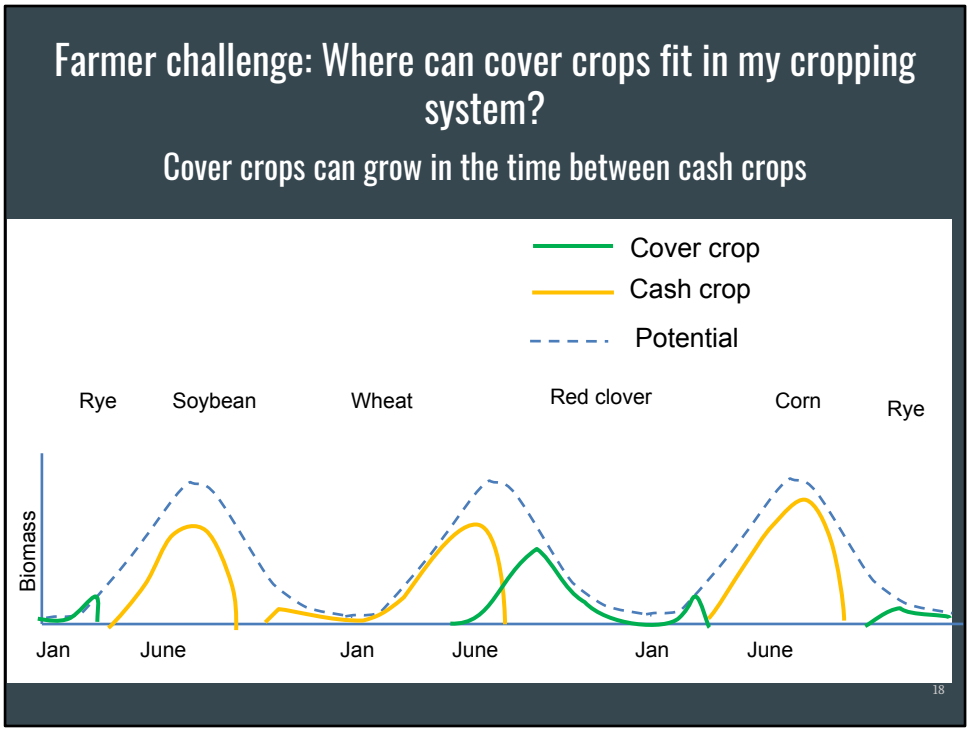


This graph shows the potential plant biomass that can be grown in an agricultural field over three years. We see three peaks on this graph corresponding to the growing season. This potential biomass shows the opportunity available for when we can be growing plants, either cash crops or cover crops.



By overlaying our current cropping system onto the potential biomass growth, we see that our cash crops still leave us space for more plant growth - these crops aren't realizing the full potential of plant growth possible. This reveals an opportunity for additional plant growth, and in this space we can add cover crops!

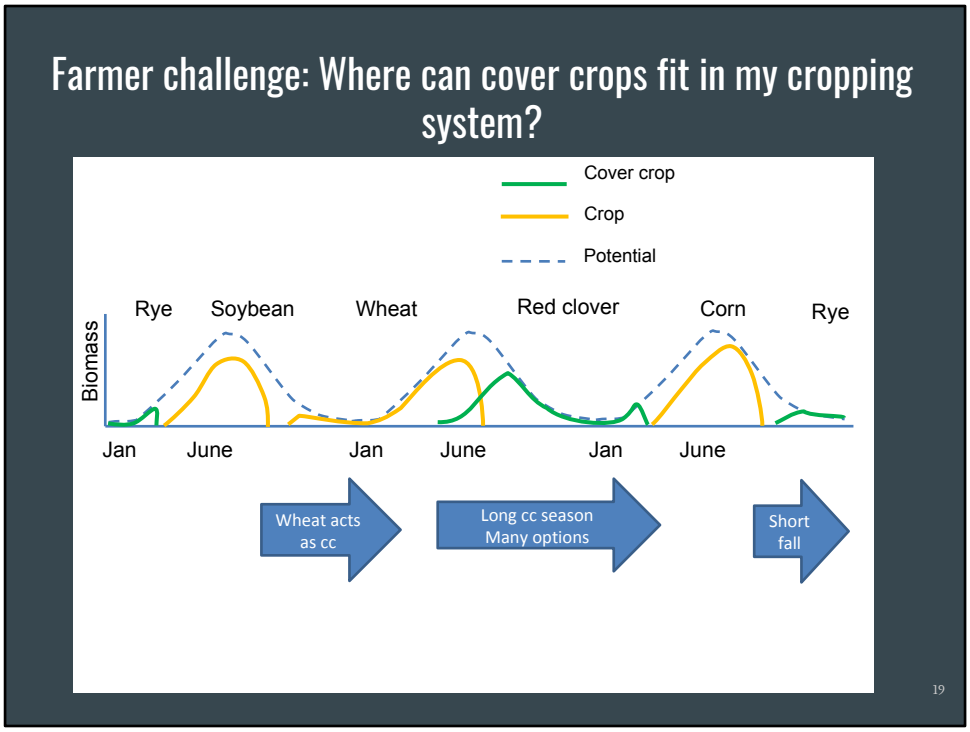
This cropping system is an example of a grain system, which includes a three year rotation of soybeans, wheat, and corn. After corn, the rotation would begin again with soy.
Note: On most farms, all parts of the rotation are present in every year. So, soy, wheat, and corn would be growing in different fields simultaneously.



In this system, there are two clear windows where there is opportunity to add cover crops. In this example, we added a cereal rye cover crop after corn (before soybean) and a red clover cover crop after wheat (before corn). In between soybean and wheat there is not enough growing potential to add a cover crop that would translate into significant benefits.

This is just one example of a way cover crops might be used in this corn→ soy → wheat → rotation, but there are other choices we (or a farmer) could make that would result in a different cover cropping scheme.

↟This would be a time to prompt students to offer other rotation examples that they are familiar with and consider if there is potential to add a cover crop somewhere in that rotation.



The potential cover crops used depend on how the cash crops are managed -

1) (First animated arrow) For example, if corn is harvested as silage, it it harvested earlier in the season allowing for time to establish a cover crop before winter. If corn is harvested as grain later in the fall, there may not be enough time left in the season to establish and grow a cover crop before winter.
2) (second animated arrow) In between wheat and corn, there is lots of time to establish and grow a cover crop, giving a farmer more options for what species to grow, and to maximize benefits provided by that cover crop.
3) (Third animated arrow) After soybean, this farmer plants wheat in the fall to overwinter. While the wheat isn't putting on much biomass at this time, it is acting as a cover crop by having ground cover and roots in the soil over the winter. Even though it is technically the cash crop, by planting it in the fall to overwinter instead of in the spring, the wheat is providing these benefits that otherwise could be provided by an overwintered cover crop.

Farmer challenge: Managing cover crops

PLANTING: Seeds can be broadcast or planted into rows with seeder

TERMINATION: Through winter killed species, herbicides, or mow/till

Timing is important!

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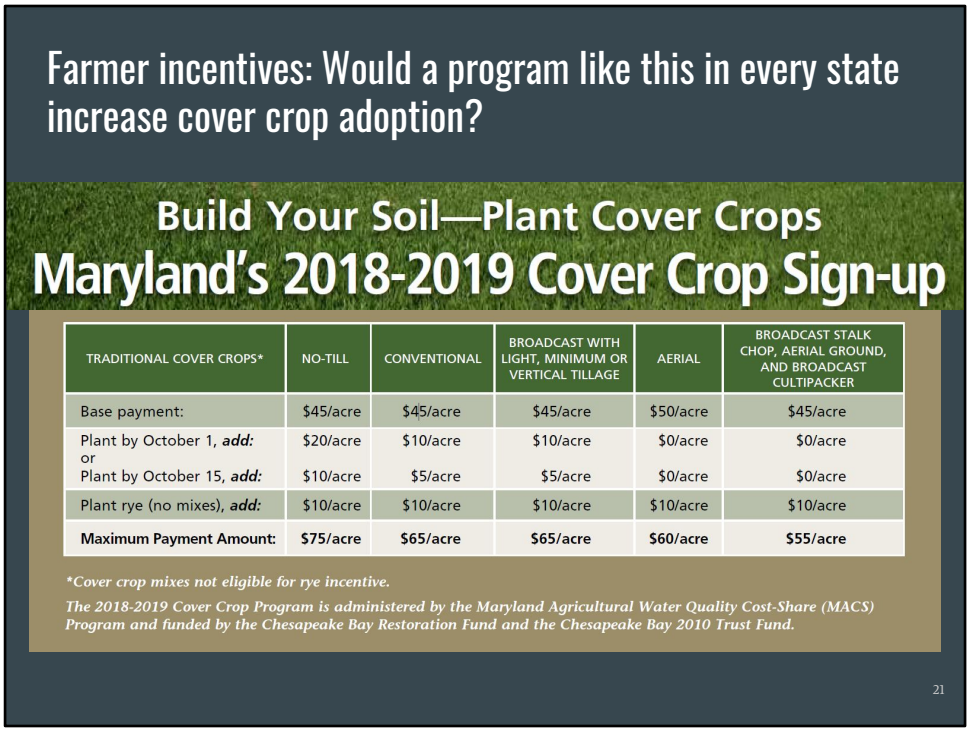
By adding cover crops to a system, farmers have also added more crops to their rotation that they now need to manage. This involves planning - both planning for the planting and termination of the cover crop, as well as the time, labor and cost involved. Planting requires the purchase of seeds, as well as a decision about planting method. Depending on time of year, soil moisture, temperature, and available equipment, planting can be done by either broadcasting or using a seeder to drill in a cover crop seed. Understanding the traits of different cover crops is especially important when considering how to terminate the cover crop. Without complete termination at a precise growth stage, some cover crops can act as weeds in the following crop. Timing is important both to maximize the benefits of cover crops on the farm, as well as to maximize the success of the following cash crops.



This is an example of Maryland's cover crop incentive program:

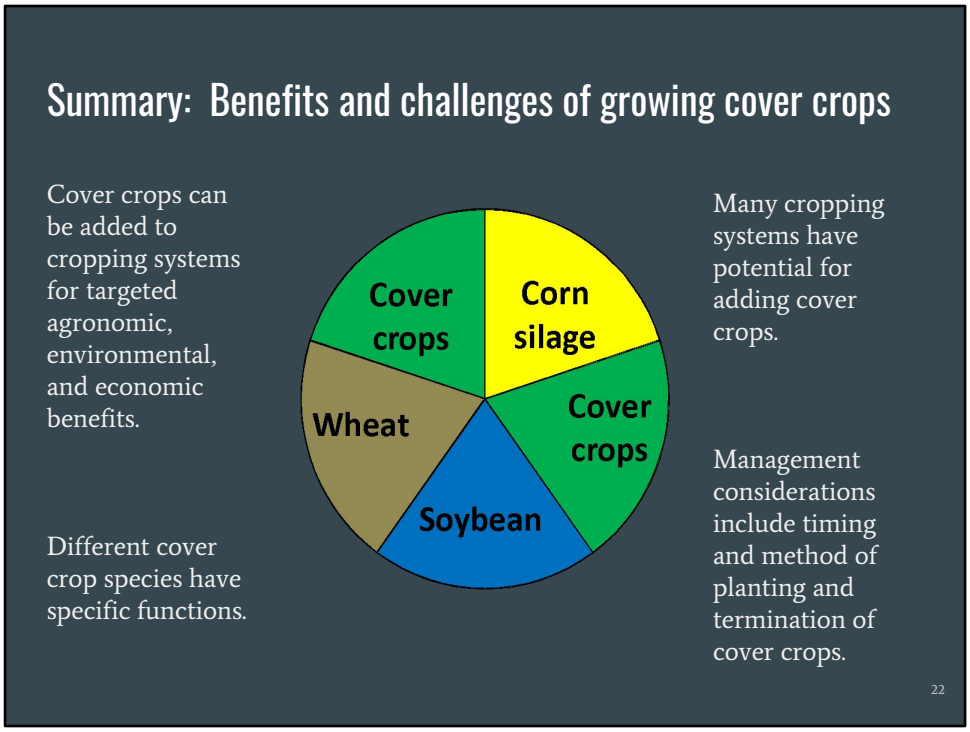
http://mda.maryland.gov/resource_conservation/counties/2018CCSignup.pdf

Maryland and Virginia currently have programs that provide monetary incentives for farmers that plant cover crops.

$45/acre base payment

Then more for:

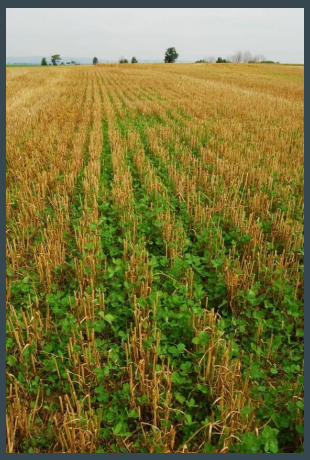
- Early planting dates
- Planting rye
- Using no-till
- Planting in targeted watershed



At this time ask if there are any further questions regarding the material

The following activity will challenge them to use the information that they were taught to make a recommendation based on a specific scenario.

If cover crops are so awesome why don't all farmers use them? What might be barriers to adoption of cover crop use?



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↟Brief class brainstorm, some barriers were already touched on including:

- Costs
- Equipment
- Labor

↟Other ideas include:

- Policy
- Risk
- Lack of Education
- No Neighboring Models
- Cost vs Benefit

↟(Not necessary to explain images to class) Picture on the left is clover that has been frost seeded into wheat. The clover was likely frost seeded into a standing wheat crop in February or so, and then wheat was harvested in July and then the clover cover crop was already established below. On the right is a mixture of vetch, clover and some grasses planted in August and this picture was taken in the next spring.

Case Study Activity

Based on the information in the case study, make a cover crop recommendation for the farmer and be prepared to defend your choice.

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↟ At this point you will break students into groups and pass out the Case Study Handout to do the active learning exercise on selecting cover crops for hypothetical farms. The following slide provides some characteristics of specific cover crops. It is also included in the handout for the case study activity.

Clover: (many varieties exist – they are all legumes that fix N). Crimson clover grows rapidly in the fall but frequently winter-kills. Red clover is often frost-seeded into wheat in which case it makes great fall cover, over winters, and continues to fix N in spring. Otherwise, summer and fall plantings of red clover give poor stands. Flowers in spring, but low floral density. Poor at weed suppression. A poor competitor in mixtures ($23 - 28/acre).

Austrian winter pea: A legume/Nfixer.Planted in early July or early August it will grow rapidly in the fall, but then the winter winter kill. Planted in September, it will have little fall growth and strong spring growth. Can flower in fall or spring depending on planting date, but with low floral density. Weed suppression is just OK. Poor competitor in mixtures($50 - 70/acre)

Hairy vetch: Very strong N fixer: Can supply enough N for a whole corn crop. Slow fall growth followed by exponential spring growthas soil temperatures increase. Of the legumes, this is the one that can be planted latest(e.g. October) and still survive. Organic farmers don't like vetch because it is hard to kill. High floral density but only for a short window in spring. Fairly competitive in mixtures with high organic matter inputs to soil($40-60/acre)

Cereal rye: Winter hardy grass; very reliable; Can plant late (e.g. Nov) and still have a large stand in spring. Great N scavenger. Probably the most common and trusted cover crop in the C'bay region. No flowers. Strong weed suppression. High root production and organic matter inputs to soil. Good N scavenging in both fall and spring. Can out compete other species in mixtures.Triticale and Spelt are alternatives ($25-35/acre). In many areas you can get a government subsidy of >$50/acre to plant rye to prevent pollution.

Oats: Winter kills after rapid fall growth. Can be planted into October. Very good grass for fall erosion protection and N scavenging. No flowers. Strong weed suppression. The most rapid fall grower ($25-35/acre)

Forage radish: A brassica that winter kills. Also called tillage radish. Needs to be planted before the end of September. Very rapid fall growth offers good weed suppression. Large tuber increases infiltration and breaks up compacted soils; flowers early to provide pollinator resources; very responsive to field N – grows fast in fields with high N. Tuber decomposes and disappears over winter.($20-35/acre)

Canola: A winter hardy brassica. The most reliable and dense flowers among these cover crops, flowers early to provide pollinator resources. Strong fall growth and in mild winters also strong spring growth. Should be planted by the end of September. Good weed suppression. Very responsive to field N; grows fast when soil is N rich. Has a big tap root, but not a tuber like radish. ($15-30/acre)