

## **Blossoms - Tragedy of the Commons**

[00:00:00.00]

[00:00:00.98] [MUSIC PLAYING]

[00:00:00.00]

[00:00:25.61] ABBY HORN: Hi, I'm Abby Horn.

[00:00:27.13] MAITE PENA: And I'm Maite Peña.

[00:00:28.73] ABBY HORN: And we're students at the Massachusetts Institute of Technology, but today, we're here in Eastleigh Farm, a dairy farm in Framingham, Massachusetts. We'll be taking you on a little bit of a tour of the farm today as we talk to you about the Tragedy of the Commons. Maite, don't these cows just look so happy?

[00:00:46.07] MAITE PENA: Yeah, and rightly so. Look at how much super green grass they have to eat. It's as if they have an endless supply!

[00:00:54.89] ABBY HORN: Yeah, except that it's not exactly endless. I mean, Maite, what if everyone you knew, or worse, everyone in the city of Boston, a city of two million people, tried to fit a cow here?

[00:01:07.03] MAITE PENA: Wait, Abby. You know that was exactly what used to happen, right?

[00:01:11.21] ABBY HORN: What do you mean?

[00:01:12.78] MAITE PENA: Well, today, we may be in a beautiful farm in Framingham, but sometime ago, when Boston used to be an early settlement, the farmers would actually bring their cows into the shared pasture, such as the Boston Commons, for example.

[00:01:27.72] ABBY HORN: And actually, still exists today as a beautiful public park in the center of the city that Maite and I love to run at...though I suppose I've only seen people and dogs there, never any cows. It's funny, I never actually thought about why it was called the Boston Commons, but now I'm sure I'll forever remember the historical context.

[00:01:48.80] But also, it really makes me wonder. I mean, I know the population back then is nowhere what it is today, but still, what if every single citizen of Boston decided to put their cow there? Was everyone in Boston allowed to graze a cow in the commons? Should everyone in Boston have been allowed to graze a cow on the commons?

[00:02:08.90] MAITE PENA: Abby, you ask some good questions. Uhm, I'm actually not sure about the answer. I guess it could depend on how much space we have and how many settlers there were, right?

[00:02:21.34] ABBY HORN: I think it's more complicated than that. For example, what if some people wanted to put more than one cow there? And really, what would have stopped them from doing that if it was a common space and all? I mean, if I were a dairy farmer getting paid for the total amount of milk that I produced, I would try to add as many cows as I could. After all, a farmer is a businessman!

[00:02:44.21] MAITE PENA: Well, if you put as many cows as you could, I guess I would feel that I have the right to do the same myself. But I'm really not sure we would like to pack the entire field if we want to get as much milk as possible, and still have happy cows. But I really don't know. Maybe the students can help us out.

[00:03:04.67] ABBY HORN: What do you think? First of all, let's have you break into groups of four. You're going to be working with these groups for the rest of the activities that we go through today.

[00:03:13.81] So with your groups of four, can you talk about what you think would happen if every person from Boston grazed a cow here on the commons? What if you saw your neighbor bringing as many cows as he could to the commons – what would you think and do? And what do you think would have been the best strategy for dairy farmers bringing cows on the commons? And what do you think would be a bad strategy, and why?

[00:04:02.82] MAITE PENA: Welcome back. You can see that we are now in the milking area of the farm. We hope you had a great discussion, and you have discovered that the commons have some limits, and the best strategy is not to put as many cow as a pasture can fit.

[00:04:20.88] ABBY HORN: OK, so I get that we don't want to pack the commons to its limits, but we still want to make some profit here. How do we know just how many cows we should add?

[00:04:31.42] MAITE PENA: Well, it will totally depend on the field.

[00:04:35.54] ABBY HORN: OK, let's do an experiment here. Let's think like a scientist. Suppose we have a green grassy commons with some contented looking cows, each eating her daily allotted quantity of grass and each giving milk in the anticipated amount.

[00:04:52.48] Say we have 10 farmers sharing this commons. Farmer 1 places one cow there and sees how well she does. The other nine farmers observe this, and each, in turn, places a cow there. All is well.

[00:05:06.57] Farmer 1 then says, uhm, why don't I try a second cow on the commons? He then places a second cow there, and she does well, and all observe this. So one by one, each of the other farmers places a second cow on the commons, and all is still well. By this time, the commons is getting a bit crowded with cows, and there might be some concern about how many cows the commons can support.

[00:05:30.35] MAITE PENA: Maybe some are getting concerned, but there still is enough room for *me* to add another cow.

[00:05:36.62] ABBY HORN: Well, it turns out that unbeknownst to the farmers, scientists some years ago actually did a study of cow milk production available from a plot of land of this very size. They collected data about cow milk production for varying numbers of cows and how this correlated to grass availability. They found that the capacity of this commons, or the amount that it can best support, is 20 cows, meaning that as long as the total number of cows is less than or equal to the capacity of the commons to replenish its grass, in other words that the grass can grow back at least as fast as it's being eaten, each new cow placed there produces the desired amount of milk a cow can produce. Let's call this amount of milk per cow one cow unit. So from 1 cow, to 2, to 20, each new cow creates one cow unit of milk per day, up to a maximum of 20 units per day. But, and this is important, the researchers also discovered that additional cows above the 20 on the commons do not produce more milk in total, so what that means is that with 21 or 22 or more cows, one cannot get from cows grazing on the commons more than 20 units of milk per day.

[00:06:55.09] MAITE PENA: So then when the commons is at capacity, we still have room to add more cows, right?

[00:07:04.28] ABBY HORN: Right.

[00:07:06.10] MAITE PENA: So I can understand it very well, but why can't we get more milk if we just can add more cows?

[00:07:15.12] ABBY HORN: The reason the milk output per cow decreases is because the available grass per cows to eat starts to decrease. Grass can only grow so fast. It grows at a constant rate, and each cow wants her daily allotted quantity. But if the grass is eaten faster than it can grow back, supplies will start to diminish. While some of the smarter cows will figure out that they can just walk a bit further to get the grass they need, lazier cows may just start eating less instead of searching out the grass that they want.

[00:07:43.87] At this point, the commons is still *physically* able to support more than 20 cows, but at a lower production level because cows that aren't eating enough won't be able to produce as much milk. And as more and more grass is eaten, some patches will even start to die. And as this continues, after a certain number of cows have been added, the combination of grass being eaten faster than it can go back and grass dying will lead to the poor cows becoming sick from lack of food and eventually producing zero milk.

[00:08:15.19] MAITE PENA: Now I understand much better. Class, can you plot an equation that has the behavior that we have described? On the vertical axis, you will represent a total number of units of milk produced each day by all the cows in the commons.

[00:08:31.46] On the horizontal axis, you will represent the number of cows on the common. Then find the variables and plot out, on paper or on the blackboard, one or more equations that have the behavior that the scientists discovered. Is your equation a reasonable fit to this situation?

[00:09:15.06] ABBY HORN: Great job. We're sure you came up with some great examples during your discussion. Now, we're going to show you a few examples of equations, which some folks call "functions", that have the properties we've described. Now, bear in mind that these are just a few examples out of a large set of possibilities, and you may have chosen some examples that are similar or even better than ours.

[00:09:37.22] Note that the vertical axis represents the total number of units of milk produced each day by all cows grazing on the commons. The horizontal axis represents the number of cows on the commons. For 0 to 20 cows, the function is linear. At the beginning, from 0 to 20 cows, there's enough room for cows in the commons. Every new cow added will have her fill of grass to eat and will produce a unit of milk.

[00:10:03.70] MAITE PENA: But when we have more than 20 cows on the commons, the grass will be eaten faster than it can grow back. The amount of grass available to eat will start to become smaller and smaller, and soon the poor cows will not have enough grass to eat. And so they won't be able to produce as much milk.

[00:10:23.97] ABBY HORN: That's right. This function shows a sharp decrease in the milk production once the capacity of the commons is reached. This is probably too sharp, in fact, because things in nature

MaitePA 10/28/13 2:14 PM

**Comment:** I should have said "I can't understand it very well. Why can't we get more milk if we can add more cows?" and instead I said: "I can understand it very well, but why can't we get more milk if we can add more cows?".

generally happen more gradually. For example, we may expect that the equation that governs production of milk as a function of the number of cows would look a little bit more like this second function.

[00:10:45.57] MAITE PENA: What is the difference?

[00:10:47.59] ABBY HORN: Well, note that the function is still linear from 0 to 20 cows, so at the beginning, every new cow would produce a unit of milk because there's still enough grass for all. However, the behavior of this function around 20 cows is a little bit different. This time, the slope of the equation, after the turning point, that is, at the capacity of the commons, is smoother. This gradual decline demonstrates that when there are 21 cows on the commons, the production of milk decreases, but that this decrease is most extreme when the pasture is more crowded since the grass availability situation will be much worse.

[00:11:26.79] MAITE PENA: This actually looks reasonable to me. I wonder, though, how can we know which is an accurate function that represents the behavior and the capacity of this field?

[00:11:37.71] ABBY HORN: A team of experts will have to do research to determine the equation that applies to this field, but that equation will only apply to this particular field. For any other field anywhere else in the world, they'll have to do another research experiment to determine the equation based on variables such as the rate of the grass growing, of course the size of the field, the amount that's raining, and even the cows that are eating there.

[00:12:02.26] MAITE PENA: Let's assume that all the farmers already have two cows in the field; that is, we have 20 cows on this commons. And let's also assume that each farmer knows perfectly well all these functions. They took Algebra I, and they already know that the capacity of this common is 20 cows. Why would, then, any farmer want to add one more cow, knowing that it won't allow them to get any more milk?

[00:12:27.92] ABBY HORN: Uhm, that's a good question. I'm not sure. Could you guys help me out? Why do you think any farmer, knowing full well that this field has space for 20 cows, would add a 21st cow, so his 3rd cow, to the commons? What do you think would happen after that 21st cow is added?

[00:13:11.12] MAITE PENA: Welcome back. We hope you had a good discussion about what happens when you add the 21st cow. As you can see, we're now in front of a tank full of over 1,000 gallons of milk. It's good that we actually asked you to have this discussion because it gave us some time to think about the question ourselves.

[00:13:31.81] ABBY HORN: And we're not sure exactly how you all thought about it, but we'd like to share the way that we thought about it. So first of all, we're sure that you discovered that Farmer 1's self interest hurt the others while rewarding himself...but only at first.

[00:13:46.02] MAITE PENA: Actually, Abby, I'm not sure I fully understand this. Why does this work at the beginning, but then stop working?

[00:13:55.48] ABBY HORN: So we're both agreed that at 20 cows on the commons, that is, two cows per farmer, the maximum amount of milk can be produced, and each farmer gets the same amount of milk for his two cows.

[00:14:06.97] MAITE PENA: Yeah, we agreed on that before.

[00:14:10.04] ABBY HORN: The problem is that each farmer will feel compelled to add an additional cow of his own. More cows mean more milk for that farmer, and more milk means more money. But that immediate gratification only works at first. The problem is that adding each cow above 20 onto the field has one positive and one negative component.

[00:14:32.49] MAITE PENA: And we already know what the positive component is: When the farmer gets one more cow, he will get one more unit of milk. So, then, how this will end up hurting him if he already has one extra cow there?

[00:14:48.33] ABBY HORN: Well, it's not exactly one full cow's worth of milk because Farmer 1 still has that negative component to contend with. The negative component is the result of the additional overgrazing of that 21st cow, which means that there's slightly less grass available for all the cows to eat, and that means that they all produce slightly less milk. But since the effects of overgrazing are shared by all the farmers, the actual negative impact in terms of decreased milk production is only a fraction of the milk Farmer 1 gets from adding that 3rd cow. So clearly, when Farmer 1 is considering whether he should add an additional cow, he'll say to himself, "Hum... this will provide me with a full cow's worth of milk minus a small fraction of a full cow's worth of milk, which I'll lose to grass shortages across the commons. I can certainly handle that little bit of loss for getting so much more," and so he will conclude that the only sensible course for him to pursue is to add another cow to the commons, and another...

[00:15:51.10] MAITE PENA: I see! The problem is that every farmer sharing this commons will reach the same conclusion. Now, they will also try to improve their production, and we can see that as each new cow is added, Farmer 1's output drops and drops and drops until it is actually below where it was when he had two cows. And with just an extra cow each, or a total of 30 cows on the commons, the milk output situation will be worse for everyone than when they all had 2 cows each. And from there the situation will just continue to get worse, following the trajectory of the type of equation we talk about earlier.

[00:16:34.04] ABBY HORN: That's why this is called the tragedy of the commons. Each farmer feels compelled to increase his number of cows without limits, but tragically, the world we live in has limits.

[00:16:45.31] MAITE PENA: So then the problem remains: We all have an incentive to add more cows even if we know that we can't get more milk production. So, can we do something to avoid this tragedy? Are we really locked into a system that compels us to be the first one to add one extra cow even if we know that will end up hurting us in the end?

[00:17:08.62] ABBY HORN: I don't think so. I think there are multiple ways we could address this problem so that there's no tragedy on this commons.

[00:17:16.56] MAITE PENA: Are there some strategies that we can find to avoid this tragedy? Work with your groups and write a formal list of all the possible things that we can do in order to avoid the tragedy of the commons. Think about the pros and the cons, what will other people think in your village, which are the cost, is it difficult to implement?, and so on.

[00:18:00.24] ABBY HORN: Great job. Some of the options you may have identified were the option to have the farmers negotiate, to privatize the commons, to introduce a limit or a cap on the number of cows that each farmer can have, to have each farmer pay a tax for each cow that he buys, or to educate the farmers on what happens when too many cows are added to the commons.

[00:18:24.66] MAITE PENA: But wait, Abby. When you say negotiation, do you mean getting everyone to agree that they're not going to put any other cow in the commons once the total production is starting to decrease?

[00:18:38.11] ABBY HORN: Yeah, or to get the farmers to work together to be creative about how they could increase productivity in the commons. For example, they could all save some money and then invest it in fertilizer that would then increase the rate that grass grows. And with more grass, they could fit more cows on the commons. But negotiation can be super complicated. I mean, what if there's one stubborn farmer who just will not agree to whatever everyone else is agreeing?

[00:19:06.80] MAITE PENA: You're right. Negotiation usually takes a long time and requires unanimous collaboration from everyone. When was the last time that you get all your friends to agree and stop doing something that is giving them instant gratification? Actually, if there is one farmer that is not willing to cooperate, it will be extremely difficult for the others to enforce him to do so.

[00:19:31.75] ABBY HORN: Well, I bet the government could help out here by introducing a policy that would control the number of cows in the pasture.

[00:19:39.14] MAITE PENA: Yeah, I think you're right. Government policies are good options to tackle these problems, although I think they also have some drawbacks. Imagine, for example, that a town council establishes a law that puts a cap on the number of cows per farmer.

[00:19:56.85] ABBY HORN: Well, to be fair to their citizens in establishing that law, they would need to do a huge amount of work to study every single pasture in their township at the same level of detail that the group of scientists who issued their report for this pasture did for us and our 20 cows, determining the maximum capacity for each.

[00:20:15.66] MAITE PENA: Carrying out this study in every single pasture has a cost and entails a lot of work, and still worse, a law limiting the number of cows per farmer could prevent the farmers from getting together and finding more creative solutions. In addition, these types of solutions are not very flexible. What would happen if a new farmer shows up wanting to start operations on the pasture? How could we make room for his cows in the commons? Should we change the cap for everyone every time someone shows up?

[00:20:51.94] ABBY HORN: Well, I guess an option that still takes advantage of the government's help in implementation but is more flexible than making a specific law on cow caps would be to make farmers pay a tax on each cow that they buy. This tax would disincentivize farmers from purchasing excessive numbers of cows because it would be just too costly to do that. You can probably think of some taxing schemes that could even further disincentive farmers from adding more and more cows.

[00:21:19.64] MAITE PENA: And I bet there are pretty good things we could do with the money raised by the tax. We could actually buy fertilizer. But remember that there is also a cost associated with collecting the tax. So indeed, all this discussion shows that this solution has advantages and disadvantages...but the fact that there are so many is actually inspiring!

[00:21:42.56] ABBY HORN: Well, Maite, I don't mean to wipe that smile off your face, but all this talk of cows and the pasture and the tragedy of the commons-- it's all an extended metaphor, or a story, meant to illustrate a larger set of problems that we see all over the world when it comes to shared resources. Shared common resources are parts of the natural, or man-made, environment that many people have, or at least should have, the right to access. Now that we have experience with this particular example -- the cows on the commons metaphor, the problem may seem clear and the ways to prevent it may seem more or less obvious. Tragically, these types of problems show up in so many contexts and settings all around the world.

[00:22:26.25] MAITE PENA: And there are many others. I'm sure that the class can come up with many more. So, class, this is the last activity that we will do today, and it will also be the most exciting and the most important. There will be a competition with a prize for the winning group.

[00:22:42.66] Working with your group, try to come up with a list of all the Tragedies of the Common examples that you can find in your community, your country, and the world in general. Longest list wins. Be creative.

[00:22:56.98] ABBY HORN: Maite, I think they should also have to choose one of the examples that they think of, and think more deeply about ways that it could have been prevented, and what would happen if it wasn't prevented.

[00:23:07.51] MAITE PENA: Uhm, agreed. Longest list win, but you also have to think deeply about one of them, at least, to actually get the prize. Good luck.

[00:23:37.86] ABBY HORN: You and your classmates have discovered that the tragedy of the commons is present in our lives in many ways.

[00:23:43.82] MAITE PENA: But there is hope. There are solutions to these problems!

[00:23:47.69] ABBY HORN: Right, there are solutions! But a really important point to note here is that problems of shared resources will not have purely technical solutions. We bring the math into the picture to explore the consequences of various actions, so it's really important to bring that science into the discussion. But eventually, these problems are solved by people working together.

[00:24:10.93] MAITE PENA: You may also have noted that many of these issues were not a problem until recently -- until population has grown so much. It may not have mattered how many people fished tuna in the Mediterranean Sea, or how many people chose to drive to work, or how many plastic bottles we consumed, or trees we cut down, or water we used, or carbon dioxide we emitted, until there were enough people out there for these things to really, really begin to matter.

[00:24:41.82] ABBY HORN: But some of us still need to drive to school and take showers and write on paper.

[00:24:47.53] MAITE PENA: Yeah, you're right, Abby, though I think this is something similar to what we've been discussing all this time. It's like the 20 cows. I believe there is a point below which it is OK if we do these things, but above which we may cause some damage.

[00:25:04.62] ABBY HORN: Maite, I was thinking, I wonder if this could go in the opposite direction, like a reverse Tragedy of the Commons.

[00:25:13.22] MAITE PENA: What do you mean, Abby?

[00:25:15.18] ABBY HORN: I mean, imagine if everyone put something in, and then there's this turning point above which there is a net benefit for everyone!

[00:25:24.31] MAITE PENA: Uhm, that could be a good idea. What do you think, class? Do you think that there is something you can do that will help not only you, but also your friends, your family, and possibly everyone in the world?

[00:25:37.96] ABBY HORN: You know, spending the whole day here has really made me thirsty for some milk. Thanks for your attention!

THIS SHOULD BE SEPARATED: (NOT SURE IF WE SHOULD ACTUALLY HAVE SUBTITLES HERE?? WHAT DO YOU THINK??

And we're students at the Massachusetts Institute of Technology.

[00:26:14.15] MAITE PENA: Oh.

[00:26:15.46] ABBY HORN: [LAUGHING] Today, we're here at Eastleigh Farm--

[00:26:19.94] MALE SPEAKER 1: Start again.  
[00:26:20.92] MAITE PENA: Hm, that is a good idea, actually, Abby. Do you think that-- whoa. OK.  
[00:26:31.86] ABBY HORN: That we can see all around the world when it comes to shared resources.  
[00:26:38.15] MAITE PENA: [LAUGHS]  
[00:26:41.69] MALE SPEAKER 2: I think that's the same one, isn't it? It keeps coming.  
[00:26:44.04] MALE SPEAKER 1: She likes you.  
[00:26:45.92] ABBY HORN: She does.  
[00:26:47.41] MAITE PENA: Hey. I think you like my red boots  
[00:26:49.96] MALE SPEAKER 1: That's what I was thinking, too.

[00:27:06.10] ABBY HORN: Hi, I'm Abby.  
[00:27:07.51] MAITE PENA: And I'm Maite. Thank you for considering this lesson.  
[00:27:10.65] ABBY HORN: So there aren't any formal math prerequisites for this lesson. Some exposure to Algebra 1 would be helpful. So now, we're going to start talking about the activities. The idea in the first activity is to get the students to realize that there are limits to the number of cows that the pasture can sustainably support, even if it can physically support more. And that's so for the reasons that we give at the beginning of scene two. So a good strategy, then, would be anything that bounds the number of cows, whereas a bad strategy would be anything that allows as many cows as you can physically fit into the commons.  
[00:27:47.54] MAITE PENA: For the second activity, any bounded function that first increases and then decreases will be valid. For the video, we chose two functions that are linear from 0 to 20, for illustrative purposes, though any other increasing function will also be valid. You may find more examples of functions in the animation that accompanies this video. This could be a good opportunity to explain or review the concept of function with your class. If you have already introduced this concept, a more subtle point that you may highlight is the fact that the functions in this problem are actually discrete instead of continuous.  
[00:28:25.67] ABBY HORN: In the third activity, we ask the students to think about the most critical aspect of the tragedy of the commons. Why would any individual farmer add an additional cow when he knows that more milk cannot be produced from the commons as a whole? The reason, as we show in the slides, is that even though the production will be less than 20 milk units, that individual farmer who added the additional cow will get almost three units of milk for himself. But of course, that's at the expense of the others. And of course, this solution is not sustainable over time because all the other farmers will then feel compelled to add one more cow for themselves, which means that in the end, everyone is worse off than if they had just stayed with two cows each.  
[00:29:09.93] MAITE PENA: So for the fourth activity, we recommend that you think about experiences in your country to address the Tragedy of the Commons that you can share with your students. This will also be a good opportunity to reiterate to your students the fact that any measure to mitigate the tragedy of the commons will have advantages and disadvantages. Discuss with them their ideas. They may come up with very good ones, even better than the solutions that we cover in this video.  
[00:29:40.29] ABBY HORN: For the fifth activity, we recommend that you discuss examples of the Tragedy of the Commons that relate to your city, your state, your community. This is your opportunity to discuss examples that are "closer to home" for your students. Then in the additional materials, we provide links to other examples of problems of shared resources that you can see all around the world.  
[00:30:05.23] MAITE PENA: We hope this video is a good resource for you and your class.  
[00:30:09.45] ABBY HORN: Thank you for your time.  
[00:30:26.11] [MUSIC PLAYING]  
[00:00:00.00]