THE COMPUTER SCIENCE UNDERGRADS HELPING FARMERS ADOPT SUSTAINABLE FARMING PRACTICES

MOST OF THE FOOD PRODUCTS WE HUMANS CONSUME EACH DAY HAVE, AT SOME POINT IN THE PRODUCTION CYCLE, BEEN SPRAYED WITH PESTICIDES TO PROTECT AGAINST DAMAGE CAUSED BY PESTS. **DR CHRISTIAN NANSEN** RESEARCHES HOW PEST MANAGEMENT, BASED ON PESTICIDE APPLICATIONS, CAN BE OPTIMISED TO ENSURE BOTH PROFITABILITY AND SUSTAINABILITY. TO PUT HIS RESEARCH INTO PRACTICE, HE ENLISTED THE HELP OF TWO COMPUTER SCIENCE UNDERGRADUATE STUDENTS TO DEVELOP THE INNOVATIVE SMART SPRAY APP, WHICH HELPS FARMERS DECIDE WHEN AND WHERE TO APPLY PESTICIDES

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FIELD OF RESEARCH

Insect ecology, sustainable pest management, remote sensing

RESEARCH PROJECT

Using innovative technologies to develop methods of targeted pesticide application.

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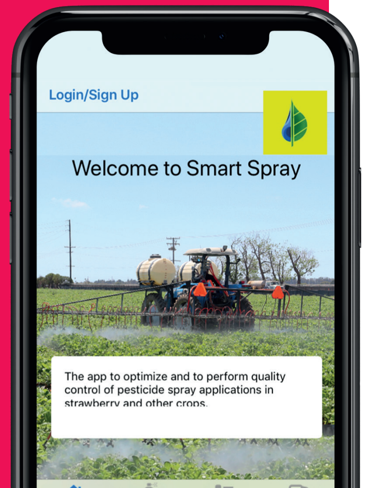
PEST MANAGEMENT AND THE DECISION-MAKING PROCESS

Imagine being the manager/owner of a farm with several individual strawberry fields – all of them larger than five soccer fields, meaning there is a lot of high-value crop under your management. You have a worker helping you with crop scouting: on a regular basis, the worker walks into the fields and looks for crop damage by pests. At some point, your worker finds 'hot spots' in some of the fields (groups of strawberry plants) with emerging outbreaks of a pest you have identified. What is the best thing to do? And what needs to be considered when making a decision on how to respond to such a pest outbreak in a crop field?

- It takes time and labour costs to perform crop scouting, so there will be a limit to how much crop scouting can be performed. But without crop scouting, farmers won't know whether they have pest outbreaks – so, what is the optimum level of scouting? Is it possible that the worker performing the crop scouting missed some emerging hot spots of pest outbreaks?
- Applications of pesticides to control pest outbreaks require spraying equipment, labour, chemicals, fuel and other expenditures – so, pesticides should not be applied unless necessary. But should the whole field be sprayed or only portions of fields? For instance, only the detected hot spots?
- Agricultural pests, such as insects causing crop damage, are known to develop resistance to pesticides. Once that happens, a particular pesticide is no longer effective against a given pest. So, the only real way to minimise the risk of pest populations developing resistance is by only using pesticides when they are causing significant crop damage. But how is that determined? And what if the prediction of risk of the pest causing significant crop damage is wrong?
- There are regulations/restrictions on how many times crops can be sprayed with specific pesticides, and applying one pesticide to control one pest may in some cases also kill 'beneficial insects' (natural enemies – other insects that actually help farmers by controlling certain pest species). It is possible that applying one pesticide to control pest A causes an outbreak of pest B. This is very similar to what is referred to, in the medical world, as the 'side effects' of drug treatments. So, which pesticide should be applied? And if you decide to apply a pesticide that can only be applied once to a given crop per season, how do you know that you won't need it again later in the growing season?
- Finally, if we assume that it is deemed necessary to apply a certain pesticide, what factors may affect the performance (how well the pest outbreak was controlled) of a particular pesticide application? The farmer needs to select the right spraying equipment as well as consider how weather conditions might affect the pesticide application performance. For example, what do you think happens if a pesticide spray application is performed under dry and windy conditions?

As you can hopefully appreciate from this brief introduction about the decision-making process associated with pest management, there are lots of factors to take into account, and making the 'right' decision is difficult. Also, the possible consequences of making the 'wrong' decision can be very costly – either wasting money on pesticide applications that were not necessary or losing money because the pest ruined the crop! In addition, you can hopefully appreciate the many similarities in decision-making between the medical diagnostics of our own health and the diagnostics used to successfully manage risks of pest outbreaks in farming systems. Just as doctors in the health care sector need equipment and guidelines to make decisions – these are generally referred to as decision support tools – applied research in pest management is heavily geared towards developing user-friendly and reliable decision support tools for farmers. This article is about such a decision support tool, which was developed in collaboration with undergraduate students.



The decision support tool is in fact a smartphone app, which has been developed and offered freely to farmers to help them make challenging decisions on how to optimise pesticide applications. To unpack why smartphone technologies like these can make farming so much better for people and the environment, we begin by peeling back some of the 'layers' involved in food production. Think of it like peeling an onion. First, we investigate why crop pests are such a problem; moving on, we find out how humanity has dealt with such pests historically; then, we examine how modern solutions could be better; and then we consider technologies that can help usher in these new solutions, such as the Smart Spray app that Dr Christian Nansen and his team developed. Finally, we look at how bringing in people from a range of backgrounds has benefited sustainable pest management and what opportunities might lie in store for you to get involved.

OUTER LAYER OF THE ONION:
Pests: why are they a problem?

SECOND LAYER:
How did we deal with pests?

THIRD LAYER:
Are there other ways to deal with pests?

FOURTH LAYER:
The Smart Spray app

FIFTH LAYER/ONION CORE:
How might you get involved?

PESTS AND FOOD PRODUCTION

Most historians agree that the advent of civilisation is marked by the development of agriculture. Having a reliable food production system is central for society. However, agriculture is no easy ride; uncertainties such as weather, diseases and fluctuating demand can make it a highly unpredictable sector to work in. The impact of pests is one such significant uncertainty, as outbreaks can decimate crop yields if not properly addressed. Among major global food crops, pests and pathogens (disease-causing organisms) decrease yields by 10-40%. Agricultural crop pests can be any animal, plant or microbe that directly damages crops and causes a yield loss. There are a wide range of pests for any crop and it is difficult to predict which will cause problems in any given year. There are many ways to both minimise risk of pest outbreaks in crops (preventive measures) or respond to emerging or established pest outbreaks (responsive measures). Among responsive measures, farmers can release/spread natural enemies, which are insects that are known to control specific pest insects. An example is lady bugs, which are known to feed on aphid pests. Use of natural enemies in pest management is referred to as biological control. Another category of responsive measures is applications of pesticides, and in most farming systems this is the most widely used responsive approach to pest outbreaks.

THE COMPLEX ISSUE OF PESTICIDES

As their name suggests, pesticides are chemicals that kill pests. They can be extremely effective and can cause dramatic declines in pest numbers. People have been using pesticides in one form or another for thousands of years. The earliest known example is from ancient Mesopotamians who dusted their crops with sulphur to deter insects. From the 15th century until the 1950s, arsenic was the principal component of dominant pesticides, but since then they have become more sophisticated. Pesticide improvements were a central part of the 'Green Revolution' in the 1970s, where advances in technology, synthetic chemicals and crop breeding boosted crop yields and prevented mass starvation. They have been used extensively in agriculture ever since. However, despite their contribution to productivity, pesticides are certainly not without their downsides. For instance, neonicotinoids is a group of pesticides, whose widespread use has been partially linked to the collapse of bee colonies. Bees and other pollinators are not only beneficial to many crops but also integral for ecosystem function. This has led to neonicotinoid usage becoming highly restricted in the EU and elsewhere.

Pesticides applied to a crop field can also impact surrounding areas, either by blowing in the wind (referred to as 'spray drift'), leaching into ground water or being washed away by rainfall. The risk of spray drift is mainly caused by a combination of unfavourable weather conditions (high wind and low humidity) and pesticide droplets being so small that they can easily drift away and enter neighbouring water bodies and fields, woodlands and urban areas. Spray drift is a problem for two main reasons: firstly, it may cause pollution and harm to non-target organisms and, secondly, it means the pesticide is blown away from where it is needed, so its application becomes a waste of time and resource for the farmer.

There are also human health concerns to account for. For example, spray drift from fields to urban areas means that residents may end up with pesticides on their skin or even in their lungs. The jury is out on whether pesticide residues left on food have an adverse effect on people's health but, certainly, their presence reduces the food's appeal to the consumer.

SUSTAINABLE PEST MANAGEMENT

Widespread and frequent pesticide applications is therefore not a sustainable solution – but what are the alternatives? A more in-depth knowledge of how crops and ecosystems work is needed to answer this. Agricultural science has advanced in leaps and bounds in recent years and we now have a much deeper understanding of how to suppress pests without relying exclusively on pesticide applications.

One important point that has become increasingly clear is that merely using less pesticide (lower dosage) isn't a solution unless approached very carefully. Low or inconsistent pesticide spray coverage may not only result in poor pest control – it can also increase the risk of pests becoming resistant to pesticides. If pests are only exposed to a low dosage of pesticide, only the most susceptible are killed. Those that survive will have some tolerance to the pesticide – and they're the ones that reproduce, passing on their genes for tolerance to the next generation. This process, known as resistance evolution, can lead to particular pesticides becoming useless against pests. The same thing can happen with antibiotics in humans. To combat the emergence of resistant bacteria, doctors always recommend that you finish a course of antibiotics.

Yellow spray cards turn blue when hit by liquid such as a pesticide formulation. Farmers use the Smart Spray app to calculate the spray coverage (percentage of blue on the yellow spray card).

So, reducing the amount of pesticides used needs some very careful thought. The pesticide has to kill almost all pests in order to prevent resistance evolution. How do farmers achieve this if they are to reduce the amount they use? Making sure that pesticides are used in the most effective and environmentally-friendly way possible is a key step in making agriculture more sustainable.

TRAINING TECHNOLOGY

Technology, coupled with scientific understanding, is a key part of solving this puzzle. Christian is one such researcher who, along with a team of undergraduate computer science students, is using smartphone technology as a platform for decision support tools to farmers. They have developed a smartphone app called 'Smart Spray', which helps farmers optimise when and how to apply pesticides.

Smart Spray uses a predictive computer model. This means that the user feeds information into the Smart Spray app, which then generates predictions of spray coverage. Weather apps are a good example of this; if you want to know what the weather might be like in a certain place on a given day, the app uses data from weather stations and predictive modelling to provide you with a forecast.

Perhaps surprisingly, a predictive computer model has to be 'trained' to work effectively. This involves feeding in 'template' information – telling the model which inputs lead to which outputs. For a weather app, for example, this information comes from vast data banks documenting how certain conditions – such as atmospheric pressure – lead to certain weather outcomes.

To train the models in the Smart Spray app, Christian's team collected field data from spray cards that change colour when they get wet from the pesticide spray. These cards were placed at various locations throughout strawberry fields. The team then recorded the outcomes of a range of different pesticide scenarios: for example, making a note of what happened when different spray nozzles were used or when the weather was good or bad. Once a large number of different scenarios had been recorded, the models started to generate reliable predictions.

Simply recording the outcomes of a few scenarios isn't enough for the model to work well, however. Christian needed a lot of variables. So, the team recorded variables such as different weather conditions, the size of strawberry plants and how they were grown, the type of spraying equipment used, the amount of pesticide applied, and the speed of the tractor. For each scenario, they noted the colour changes on the spray cards – which indicated how much of the pesticide had reached the crops – and inputted the findings into the model's training data set.

SMART SPRAY

The Smart Spray app can help farmers use pesticides in ways that minimise the risks of spray drift and maximise their ability to protect crops from pests. The app has two basic functions: it can be used to predict the amount of spray coverage needed as well as show how successful the pesticide application was.

The app's predictive function runs algorithms after users of the app have entered information about the crop, weather conditions and other operational settings.

To fully understand how the app works, we encourage you to download it from the Android or iOS app store – simply search for "Smart Spray" and look for a yellow symbol with a droplet/leaf. You can also download a manual and follow download instructions on this website: http://chrnansen.wixsite.com/nansen2/smartspray.

Smart Spray has been designed for strawberry growers, but the team plans to adapt it for other crops, such as almond, pistachio and tomato. As well as benefiting farmers' pockets, it is also good news from an environmental perspective. Most obviously, the app means that less pesticide has to be applied, so fewer non-target organisms will suffer. Additionally, the app informs farmers to delay spraying if there are unfavourable weather conditions that would result in pesticide spray drift.

Meet Gabriel del Villar de Santiago and Alexander Recalde, two undergrad computer science students

It is thanks to an unusual collaboration that Christian was able to develop the Smart Spray app. Building the app was beyond the scope of agricultural scientists or entomologists (people who study insects), such as Christian. Teaming up with computer science undergraduate students provided a unique solution. Christian provided the agricultural expertise, while the students used their coding skills to build the app's digital structure and user interface.

Gabriel and **Alexander** are computer science undergraduate students at the University of California Davis in the USA. They tell us how they ended up working with Christian and how the project has benefited their career prospects.

Gabriel del Villar de Santiago

A fellow computer science undergraduate recommended that I apply to work with Christian on the Smart Spray app. I have an interest in health and wellness, and I care about where the food I eat comes from. Additionally, I wanted to learn more about the processes behind growing, cultivating and bringing foods to market. My generalist mindset means that I am interested in how technology can be applied to solve problems outside of pure computer science.

I led the development of the iOS version of the Smart Spray app and was heavily involved at every stage of the process. This included launching the app on the Apple App Store, prototyping future versions of the app and helping to improve the underlying algorithms within the app.

One of the most challenging aspects of designing the app was ensuring it was easily scalable. We wanted to be able to efficiently add more crops and features in the future. Because the app caters to a niche market, namely farmers and crop sprayers, we also had the extra challenge of developing a user interface that caters to a very specific user.

It is a source of pride for me that the merging of two disciplines – application development and entomology – gave us the tools to solve problems for sustainable agriculture. Working with Dr Nansen was a fun and rewarding experience, and it feels fantastic to have had a positive impact.

I have always taken an interest in development and design. I have wanted to be an engineer or architect from a young age. During school, I enjoyed solving problems using technology, so computer science seemed like the ideal path for me.

Once I graduate, I hope to use my degree to build apps to benefit the health and wellness sector. This could mean building software for sustainable food production, for hospitals, or to help people with fitness or nutrition. One of the best aspects of studying computer science is that you can apply your skills to a wide variety of disciplines. If you enjoy creativity, critical thinking and problem solving, computer science could be for you.

Alexander Recalde

I got involved in the Smart Spray project when Dr Nansen reached out to the Computer Science Department at the university. I had some experience as a mobile developer, so it seemed like a good fit. I was curious to see how technology would be used in other fields and this was the perfect way to explore that.

I developed the Android version of the app, so Gabriel and I worked closely together. We wanted our app versions to behave identically, and it also helped to collaborate on problem solving. For instance, Gabriel showed me a way to drastically reduce runtime on a new feature.

At first, it was a challenge to not have a senior person telling me exactly what to do. I had to teach myself how to finish each task on my own. Although this was challenging, it was a good learning experience and I am proud that I managed to put everything together. Now, there are farmers who have a tool to help optimise pesticide application, which has led to lower pesticide usage on crops as well as less contamination of the environment. This is a great source of pride for me.

When I was younger, I wanted to be an astronaut or an inventor. After that I wanted to be a businessman and then landed on becoming an engineer. After my first year of high school, I knew I wanted to specifically become a software engineer. I had started coding years before, right after watching The Matrix at 9 years old. I began by coding a basic rock-paper-scissors game and fell in love. By the time I reached high school I was coding non-stop.

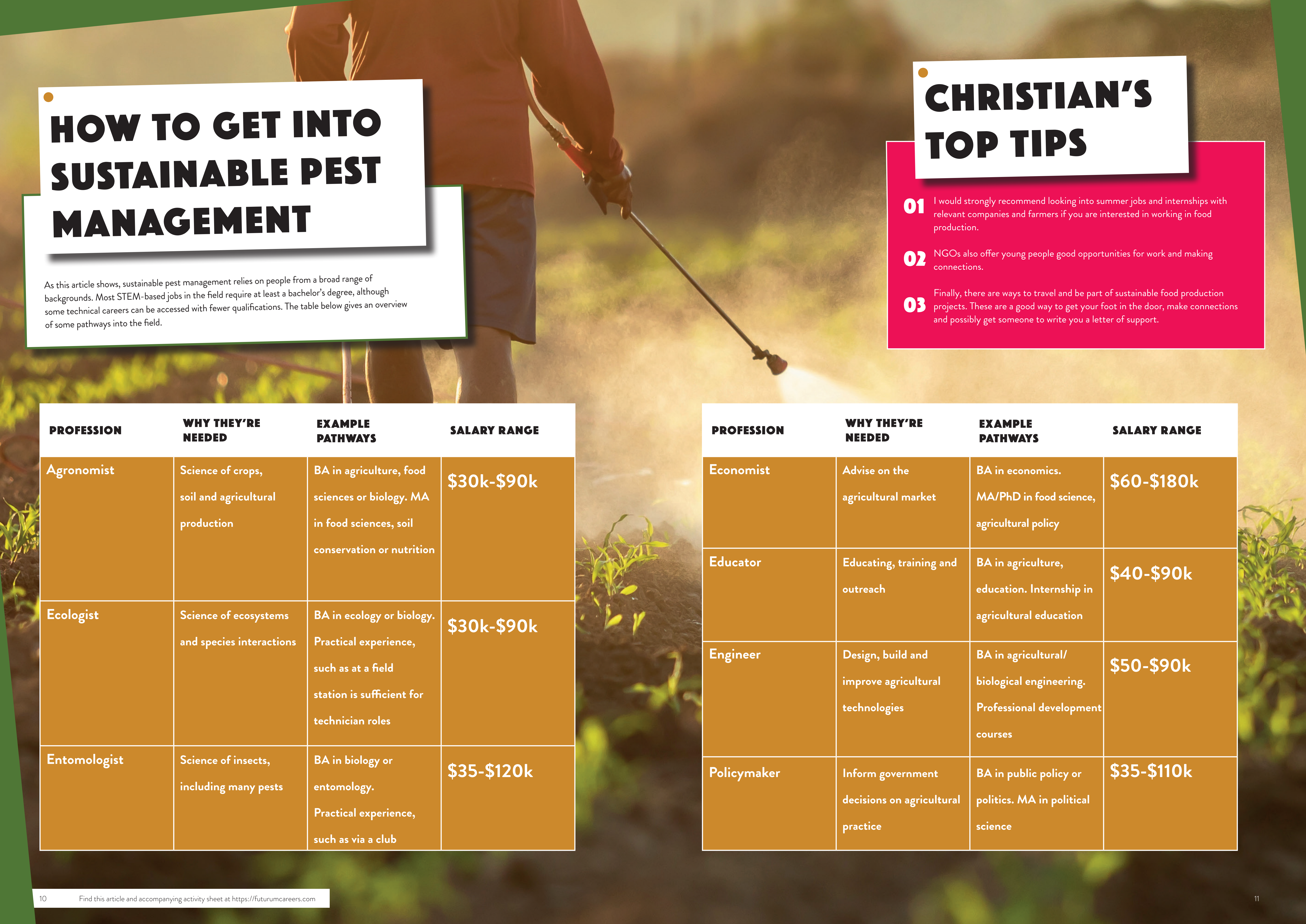
I have a job lined up for when I graduate. I will be working for a company called Esri which designs Geographic Information Systems (GIS). My work will benefit farmers but will not be as focused as this project. I will probably move back into agricultural technology eventually, but the start of my career will be more general.

Working with Dr Nansen was a great experience. It gave me the opportunity to see how technology can be applied to different fields. I went to a farmers' conference, where I learnt how technology is being used throughout agriculture.

I would advise trying out coding before beginning a computer science class. I know a lot of people who dropped out of computer science classes because they did not enjoy coding. Although it's fun to do coding for coding's sake, it's often more fun to do your own project. There are plenty of resources out there where you can design your own website or app and beginning with these tutorials is a great first step. Even when I had difficult or boring class assignments, I never quit because I knew how much fun taking a project through to completion could be.

Gabriel, Christian and Alex with the Smart Spray app

Gabriel, Alex and Christian looking at features of the Smart Spray app. Imagine working with a researcher in this way!



HOW TO GET INTO SUSTAINABLE PEST MANAGEMENT

As this article shows, sustainable pest management relies on people from a broad range of backgrounds. Most STEM-based jobs in the field require at least a bachelor's degree, although some technical careers can be accessed with fewer qualifications. The table below gives an overview of some pathways into the field.

CHRISTIAN'S TOP TIPS

01 I would strongly recommend looking into summer jobs and internships with relevant companies and farmers if you are interested in working in food production.

02 NGOs also offer young people good opportunities for work and making connections.

03 Finally, there are ways to travel and be part of sustainable food production projects. These are a good way to get your foot in the door, make connections and possibly get someone to write you a letter of support.

PROFESSION	WHY THEY'RE NEEDED	EXAMPLE PATHWAYS	SALARY RANGE
Agronomist	Science of crops, soil and agricultural production	BA in agriculture, food sciences or biology. MA in food sciences, soil conservation or nutrition	$30k-$90k
Ecologist	Science of ecosystems and species interactions	BA in ecology or biology. Practical experience, such as at a field station is sufficient for technician roles	$30k-$90k
Entomologist	Science of insects, including many pests	BA in biology or entomology. Practical experience, such as via a club	$35-$120k

PROFESSION	WHY THEY'RE NEEDED	EXAMPLE PATHWAYS	SALARY RANGE
Economist	Advise on the agricultural market	BA in economics. MA/PhD in food science, agricultural policy	$60-$180k
Educator	Educating, training and outreach	BA in agriculture, education. Internship in agricultural education	$40-$90k
Engineer	Design, build and improve agricultural technologies	BA in agricultural/ biological engineering. Professional development courses	$50-$90k
Policymaker	Inform government decisions on agricultural practice	BA in public policy or politics. MA in political science	$35-$110k