Introduction
Dear Rector, Dean, colleagues, guests, family and friends. It is a pleasure to see you all here today.

I am a geographer, which I interpret as a licence to study anything, anywhere, and I have been fortunate enough to study a lot of different things in a lot of different places. I have spent most of my career either in agricultural research centres looking at staple crops and farming systems in Africa, Asia and Latin America or in international development and policy institutes like the World Bank and the European Commission looking at the global picture of sustainable development issues related to environment and agriculture. This lecture is a bridge between that applied science and policy support in my past and an academic future as Chair of Spatial Agriculture and Food Security. The first part of the lecture is a rapid overview of the global picture of agriculture and food security followed by some of my past work on geo-information science for food security. The second part looks to the future and how we can make the space to grow research and education for Food Security and Spatial Agriculture within ITC and UT. The theme throughout is the transition from fundamental research to actionable information and eventually societal impact. Food security is a wicked problem [1], and my role is to contribute to the best geo-spatial science to help solve it.

1 Agriculture: Facts and Figures

Agricultural land Around 40% of the Earth’s land\(^1\) is used for agricultural production, 15 million km\(^2\) for crops and 28 million km\(^2\) as pasture for livestock [2]. This 43 million km\(^2\) of land (Figure 1) is around 1,000 times the area of the Netherlands.

Figure 1 Global distribution of cropland and pastures in the year 2000. Intensity of colour represents the percentage area of each 5 min (~10km) pixel identified as cropland (green) or pasture (brown) or a mixture of both. Map credit EarthStat, Global Landscapes Initiative. [2,3].

\(^1\) This talk focuses on land based food and food production systems.
The amount of agricultural land has increased by 9% over the last 50 years either due to expansion at the expense of other land cover such as forest or due to increased cropping intensity per year, but population growth from 3 billion to 7 billion during that time means that the amount of arable land per person has reduced from 0.37 hectares per person in 1961 to 0.19 hectares per person in 2013 so that we now feed the world on half the land per person that we did in the 1960s [4].

**Production and supply** During the same time, due to higher yielding varieties, improved land and water management and increased use of inputs, the volume of agricultural production has increased two and a half times so that we can produce the same amount of food on less than one third of the land that would have been required in 1961 [4]. This impressive increase in productivity has resulted in an increase in the average food supply from 2200 calories per person per day in 1961 to around 2900 calories per person per day in 2013 [4], implying that we now have sufficient food for everyone, but huge disparities remain (Figure 2).

![Figure 2](Image)

*Figure 2* World food supply in calories per person per day, 1961 (top) and 2009 (bottom). Data from FAOSTAT [4], maps from OurWorldinData [5].
Some 800 million people suffer from hunger and over 2 billion are malnourished because they cannot afford sufficient food or lack access to food. At the same time some 30% of the food we produce does not make it to the table due to post harvest losses or waste [6].

**Farms and farm size** The operational unit of agricultural land is the farm where decisions are made on what to grow in each parcel of land. There are around 570 million farms in the world, 74% are in Asia and 9% are in Sub-Saharan Africa. Around 72% of farms (around 400 million farms) are less than 1 ha (hectare) in size\(^2\), accounting for only 8% of all agricultural land while the top 1%, which are larger than 50 ha, account for 65%. In low and lower middle income countries 95% of all farms are five ha or less (Figure 3) and account for most of the agricultural land in those countries [7]. These smaller farms produce the majority of food in Africa and Asia [8].

\[\text{Figure 3 Distribution of the number of farms and farmland area, in percent, by farm size class, worldwide (top) and low income countries (bottom). Data from FAO [7,9].}\]

\(^2\) Here a very small farm is less than 1 ha, small is 1 – 2 ha, medium is 2 - 5 ha and large is greater than 5 ha.
**Agriculture in the economy** While decreasing in importance over time in many countries, agriculture is still a major source of employment, income and economic growth. The agricultural sector directly employs around 1 billion people [10] and in low income countries the agricultural sector provides the vast majority of the employment opportunities and accounts for one third of GDP in those countries [11]. Around 2.6 billion people, 40% of the world population, mostly living on small farms in low and lower-middle income countries, depend on agriculture for their livelihood [12]. Globally, the annual value of all agricultural production in 2013 was 2.25 trillion US dollars, two thirds of which comes from crops (Figure 4) and the rest from livestock sources.

![Figure 4](image)

**Figure 4** The global value of crop production in 2013 [13]. Crop production maps for year 2000 from Monfreda, Ramankutty & Foley [14], updated national production and value of production data from FAOSTAT for 2013 [4].

**The importance of agriculture** Agriculture accounts for a substantial part of the world’s land, forms the livelihood of millions of people, makes a substantial contribution to the economy of many countries and produces goods worth billions of dollars every year. This vast amount of natural and human capital generates agricultural produce that is used for fibre, for medicine and for biofuel, but mostly it is used for food. And yet, food security remains out of reach for a substantial proportion of the world’s population, a problem exacerbated by food price crises such as in 2007-08 where a spike in cereal prices due to drought and a high oil price pushed more people temporarily into food insecurity. This severely limits the health, prospects and contribution of people to the economy. Furthermore, millions of smallholders with holdings of two hectares or less require better options for improving their livelihoods. There are real concerns about our ability to meet future food demands from our current agricultural systems.

Making sure that these agricultural systems are sustainable and healthy and are able to provide sufficient food for a growing population [15] is one of the UN’s 17 Sustainable Development Goals which aims to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture” by 2030 [16]. Hunger and nutrition are well understood concepts, and sustainability was defined and debated in the inaugural lecture of Prof. Alexey Voinov in February this year [17]. But what is food security?
2 The Evolution of Food Security

The term Food Security has been defined and redefined multiple times in research and policy usage. When it was first coined in the 1970s it focused on a single, “simple” goal - securing the provision of sufficient food. Later definitions in the 1980s recognised the need to also secure access to food, particularly for the most vulnerable people in times of food crises. In the 1990s the term evolved further to incorporate consumption and demand by securing safe and nutritious diets. Thus food security is no longer a goal per se but rather a complex set of policies, decisions and actions that support an active and healthy population. The most recent definition from the Food and Agriculture Organization of the United Nations (FAO) captures the supply and demand of food of sufficient quality and in sufficient quantities.

> “Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” [18].

The role of people and their ability to best manage their physical, social and economic resources is central to this definition. The production, access and supply of food is highly variable in both time and space, in part because the resources required to ensure adequate production, access and supply also vary. The measurement, monitoring and management of these resources is where information and geo-information has an important role to play.

3 Information for Food Security

While there is evidence stretching back 10,000 years of granaries that could store food for times of shortage, one of the first recorded information systems for food security was a water height measurement system on the River Nile some 5,000 years ago. The annual flood waters of the Nile were essential for Egyptian civilization and the Nile is still clearly visible as the source of life in Egypt (Figure 5). A moderate amount of water in the river from seasonal rains provided sufficient water and fertile alluvial deposits for agriculture, whereas too little rain would lead to shortages and famine and too much water in the river would flood the land, wash away soil and endanger lives and infrastructure. Nilometers were used to measure the water level and they were also a forecasting tool for the quantity of food that could be expected during that year’s harvest. They were also an administrative and financial tool since that harvest was taxed. Although now made redundant by water control mechanisms like the Aswan dam, Nilometers were used well into the 19th century resulting in 1300 years of written history of water levels, and indirectly of food supply [19].

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Figure 5 Nile river and delta. Image credit - Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC.
Moving to the present day, national departments of statistics and bureaus of agriculture have the mandate to collect information on food and agriculture every year. This information guides and supports policy making on agricultural production, use and preservation of natural resources, agricultural trade, rural investments, research and food safety amongst others. These national government agencies provide information to international bodies like the FAO, the UN and the World Bank, and it is these global databases that are the underlying source of data for the statistics and maps in section 1. While these capture the big picture of agriculture in the world, they do not represent the local differences in agricultural systems, nor the local variability in socio-economic and biophysical environments that affect agriculture.

The same departments of statistics and bureaus of agriculture provide sub-national information on many aspects of food and agriculture at state, province, county or municipal level\(^3\). These are derived from representative surveys and/or field samples which means a large nationwide data collection effort every year or perhaps more frequently (seasonally, bi-annually or quarterly for example). This regular data collection needs to be consistent, of high quality and representative, and if the data are to be a useful decision support tool - and not merely a historical record - then they need to be available rapidly after collection.

Meeting these criteria is a challenge for many countries, especially those in the Global South and there is a growing concern that information on agriculture derived from statistics in these emerging economies and low income countries is generally poor. At the same time, it is these countries where some of the greatest economic, environmental and development challenges exist and hence these are the places where good information is most needed to guide research and policy to address them. In “Poor Numbers: How We Are Misled by African Development Statistics and What to Do about It”, Jerven [20] outlines the urgent challenges in sub-Saharan African economic development in particular, where the paucity of accurate information limits the operations of national governments, limits the effectiveness of support from international agencies and nongovernmental agencies and limits trade and cooperation opportunities. This does not mean that statistical agencies are “broken”, though it is clear that the capacity of some falls short of what is required to generate reliable statistics.

The problem is also related to changes in the information we need to address current and future food security issues. Past approaches may have implemented the same policy or promoted the same technology in all parts of a country or region. For example, some of the greatest advances in agriculture in the past, such as the rapid gains in productivity due to the Green Revolution in the late 1960s, were due to widespread adoption of new high yielding varieties, expansion of large scale irrigation, modernisations in management and storage and, increased use of fertilizers. There was little in the way of targeting or tailoring technological solutions to different environments and so there was little need of detailed spatial information since the same package of technologies was promoted everywhere. While this led to increased yields in Asia and Latin

\(^3\) The same agencies may carry out a more comprehensive national agricultural census at least once every decade, but these costly and detailed snapshots are not a the basis of information for regular monitoring or management.
America, almost tripling cereal yields in 50 years for example, many areas that did gain have now reached a yield plateau from this “one-time” innovation [21], while sub-Saharan Africa did not see the same level of benefit at all (Figure 6). At the same time, gains in productivity from widespread adoption of agricultural technologies associated with the Green Revolution have been linked to detrimental changes in the environment such as deforestation, and a loss of biodiversity (both wild and agricultural).

![Yield gain in cereals per region, 1961-2011 (1961=1)](image)

*Figure 6 Relative yield gain in cereals for major regions in Africa, Americas and Asia. Data from FAOSTAT [4].*

Further improvement in the way we produce and provide food requires solutions that are adopted to local conditions and the diversity amongst farm households. The information we need to scope and target these interventions needs to be much more spatially and temporally detailed than the information available from traditional sources and the countries where gains need to be made are often the countries where information is at its poorest. This need has been outlined in two major efforts to improve available information for agriculture and development: the call from the UN for a *Data Revolution in Sustainable Development* [22] which emphasises the need for research and innovation in the way we collect and use data, and; the Global Strategy for Improving Agricultural and Rural Statistics [23] which directly addresses the lack of capacity to provide reliable information on food and agriculture.

While those two efforts call for better information on development and agriculture in general, the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM) makes a direct link to the use of geo-information to “strengthen global agricultural monitoring by improving the use of remote sensing tools for crop production projections and weather forecasting” [24]. The increasing quality and availability of geo-information from space, air and ground based networks clearly has a big role to play in food security by contributing to this need for better information on the *where, when, how and how much* of food.
4 Geo-information Science for Food Security

Much of my work and collaborations to date have focussed on the use of geo-spatial science for understanding rice-based cropping systems. It is the world’s most important crop for the poor, supplying over a quarter of the calories in low and lower-middle income [25]. This work has been conducted at global, regional and household level including: methods to map and monitor the crop [26–29]; where and when rice is produced [25,27,30,31]; the production situations [32,33]; constraints [34,35]; the potential exposure to flood [36,37], drought [37,38], pests and diseases [32,39,40]; the changing preferences of producers and consumers [41,42]; market linkages [43] and; the potential impact of improved varieties or technologies [44–46]. Although limited to one crop, the way in which colleagues and I have used geo-information to look at this range of issues from production through to consumption in rice systems at IRRI holds true for many other crops and cropping systems.

I will highlight a few pieces of past work that I think reflect the importance of research to determine the most robust and reliable ways to generate information on crops, cropping systems and crop management.

Working with Mirco Boschetti, Francesco Nutini, Giacinto Manfron and Pietro Alessandro Brivio at CNR-IREA, we looked at how crop management practices can be detected with remote sensing [26]. Lowland rice is typically grown in flooded conditions where the field is deliberately flooded at the start of the season and surface water is clearly visible during land preparation and transplanting (Figure 7). As the plant grows, the canopy slowly closes until it completely covers the underlying water. In typical conditions the rice crop remains ‘flooded’ until the field is drained at the end of the season for ease of harvesting.

Figure 7 Bundling up of seedlings in a nursery ready for transplanting. Myanmar, January 2013 (Photo A. Nelson).
Although there were many rice detection and mapping methods in the literature, we could not find any study related to the most robust way to detect this widespread practice. Through an analysis of the spectral response of soil and water combinations before, during and after this period of crop establishment we were able to demonstrate and validate which combination of bands was most diagnostic for flooding and which spectral index performed best in detecting flooding (Figure 8). This in turn led to a robust method that used multispectral imagery such as MODIS, Landsat or Sentinel-2 for detecting both where and when rice crops are established [36].

**Figure 8** Top - Comparison of different surface responses in different spectral ranges: full range [0.35–2.50] (A), visible [0.35–0.75] (B), near infrared [0.75–1.35] (C) and, shortwave infrared [1.40–2.50] (D). Bottom - Behaviour of spectral indices (NDSIs) in different paddy rice conditions. Based on Figures 2 and 3 from [26].
One of the most challenging aspects of monitoring and mapping a staple crop like rice is that it is grown on over 165 million hectares in more than 100 countries across the world in a wide range of environmental and socio-economic conditions. Much of the world’s rice is grown in Asia (Figure 9) where the monsoon rains and tropical storms coincide with the major rice growing season (Figure 10). This places the crop at high risk to wind and flood damage and the pervasive cloud cover makes observation with optical remote sensing highly challenging.

**Figure 9** Major rice growing areas in Asia, circa 2000-2010 from MODIS. Based on Figure 3 from [47].

**Figure 10** Monthly rice area (millions of hectares) in Asia and the average number of tropical storms per month in the western Pacific between 1959 and 2011. Based on Figure 1 from [36].
This led to a long term collaboration with Francesco Holecz and colleagues at Sarmap on the use of multi-temporal SAR imagery for rice monitoring. While there were many studies in the literature on the use of SAR backscatter for rice monitoring - due to the capability of SAR to penetrate cloud and the unique temporal signature of the backscatter coefficient for rice - no study had tested if these methods were robust across a range of management practices, environments and varieties typically found across the rice growing areas of Asia. Working intensively for three years with many partners across six countries and thirteen different sites in South and South East Asia we developed and validated a new method (Figure 11) for rice detection that was accurate for irrigated and rainfed systems, for transplanted and direct-seeded establishment methods, for short, medium and long duration varieties in single, double and triple cropped systems [27]. This is a nice example of a robust crop detection methodology using multi-temporal remote sensing information that can be easily tuned to local conditions.

Both of these optical and SAR based approaches to monitor rice are now being used by Tri Setiyono and colleagues in IRRI to extract information such as the date of crop establishment and leaf area index (LAI) which in turn are used to estimate yield in crop growth simulation models. The temporal information is also being used to assess the exposure of the crop to different stresses such as drought, flood, heat and cold stress, especially during the critical growth phases when such stresses can lead to sterility or total crop loss.

*Figure 11* Rule-based rice detection algorithm for multi-temporal backscatter images. Based on Figure 3 from [27].
Pests and diseases are one of the major causes of yield loss, reducing rice yields by up to 15% in tropical Asia in situations where the diseases can occur every year (chronic) or occur infrequently but with heavy losses (acute) [48]. With Serge Savary and Laetitia Willocquet (now with INRA) and Jorrel Aunario (IRRI) we developed a simple proof of concept of how to link the EPIRICE model of potential epidemics to spatial information on the where and when of rice and weather conditions during the growing seasons [40]. The work showed that the simulated outputs from the EPIRICE model had a good fit with published disease progress curves and that with sufficiently good spatial data on rice cropping systems we could map the potential plant disease epidemics of five major rice diseases (Figure 12). It also highlighted the lack of publically available field data to better parameterise and validate crop health models which is still a challenge for estimating the impact of pests and diseases on crops.

*Figure 12* Global maps of simulated rice disease epidemics. Mean values of the area under the disease progress curve (AUDPC) for years 1997–2008 for leaf blast and sheath blight. Based on Figure 2 from [40].
New agricultural technologies can have a positive impact on the livelihood of farm households, on the environment and on the consumer. Knowing where and when these technologies can have the greatest positive impact is essential for maximising their adoption and also reducing the risk of adverse effects if the technology is adopted in inappropriate environments.

Irrigated agriculture accounts for 70% of water withdrawal globally. To meet growing food demand, the amount of water used for producing food and fodder crops is expected to increase at a rate of 0.7% per year [44]. Climate change and increased competition with other uses is likely to lead to water scarcity in many areas. Water saving technologies – more crop per drop – are likely to play an increasingly important role, but where can they be safely adopted without reducing yield? One water saving technology is Alternate Wetting and Drying (AWD) where farmers switch from a continuously flooded field to a field that has several dry phases through the season. Rice requires two to three times as much water as other field crops, and AWD has been shown to reduce water consumption by up to 30% without a yield penalty. It also results in a reduction in methane emissions from rice fields and major rice producing countries see it as a way to reduce their greenhouse gas (GHG) emissions, but there have been no quantitative assessments of AWDs viability that would be required to trigger changes in national policy.

With Reiner Wassmann, Ole Sander and Leo Palao at IRRI, we developed a simple, spatial water balance model [44] to estimate the seasons and areas that are climatically suitable for AWD, providing a realistic upper bound of the potential area. We found that a substantial part of the wet season rice area was climatically suitable (Figure 13), contradicting the notion that AWD is unsuitable during the monsoon. This is significant since most rice is grown in the wet season, so the potential benefits of AWD for saving water and mitigating GHG emissions could be higher than anticipated. The method provides a framework to assess potential water savings and methane emission reductions, both of which are currently unknown and both of which could be substantial. National level assessments are ongoing in Vietnam, Bangladesh and the Philippines.

**Figure 13** Proportion of the wet season rice area in Cagayan province, Philippines deemed to be climatically suitable for AWD for different model settings accounting for uncertainty in percolation rates. Based on Figure 8 from [44].
Much of this work has culminated in a major collaboration between public and private research partners and the Department of Agriculture (DA) of the Philippines to develop a nationwide Philippine Rice Information System called PRISM (Figure 14). Rice is by far the most important crop in the Philippines for food security, where rice is typically consumed three times a day where average per capita consumption is around 120 kg per year compared to 5 or 6 kg in Europe. It is also an important source of employment and livelihood in rural areas [42]. Timely and accurate data on the rice crop provides the DA with information that can support import and export decisions, resource allocation for boosting productivity and disaster response coordination.

Led by IRRI (with Alice Laborte and Adam Sparks) and PhilRice, PRISM uses the SAR and optical remote sensing methods we developed [26,27,36] to monitor rice area, seasonality, flood and drought. Through field experiments it also developed and implemented standardised field protocols to assess crop health, pest and disease presence, farmer practices and crop biophysical parameters. Most farmer, crop and crop health information is collected via mobile phones, including photos, location, LAI, management practices and pest presence/damage estimates and transmitted over the mobile or Wi-Fi network to a cloud-based database. Finally, crop simulation models that use remote sensing derived crop parameters forecast and estimate seasonal production. The cloud platform provides project partners and users with access to the remote sensing and field data and status reports. PRISM is now providing the DA with seasonal information at national, regional, provincial and municipal level, with the aim to transfer PRISM to the DA so that it becomes part of their operational activities.

I think it is a good example of how partnerships in geo-spatial research in different aspects of crop production can really have an impact by strengthening the capacity and infrastructure of a country to use information and geo-information technology for a more food secure future.
5 Space to Grow

I have presented a few examples of geo-spatial analysis and models in food security and how these can be integrated into operational systems that provide policy makers with some of the information they need to implement more sustainable agricultural systems. I covered only a part of what I think can and must be done, but these examples are a platform from where I see the space to grow research and education for Food Security and Spatial Agriculture within ITC.

**Research** There is a need for better information on where crops are grown. Developing robust methods to detect and monitor different crops, particularly staple grains, pulses, forage crops, tubers and vegetables will require research on the best use of a combination of temporal and spectral information from an increasing number of satellite and airborne sensors. While I have been involved in successful efforts to map and monitor rice areas at high temporal and spatial resolution in Asia, I would like to see similar progress with other crops in other regions where our current knowledge of their distribution is lacking and also where there are gaps in our knowledge on the best methods to detect and discriminate between them.

There is another fundamental data layer on agriculture that is simply missing in many parts of the world. Knowing where fields and field boundaries are is essential for the correct interpretation of our observations of the land surface and vegetation cover at a level of detail that relates directly to land management. Significant advances have been made in the automatic extraction of field boundaries from high resolution imagery [49] in the USA where fields are regular, well demarcated and have an average size of 10 hectares, which is at least 10 times the size of many fields in Africa and Asia, many of which are irregular and not well demarcated. Work is ongoing in the STARS and its4land projects for example with much higher resolution satellite or UAV imagery, and this could be a solution for many areas, but there may be limits to what can be automatically extracted from diverse and complex landscapes. Crowdsourcing approaches where paid teams or volunteers browse online archives of imagery and manually digitize visible field boundaries is also a viable option and can quickly cover large areas, but methods to validate and assess the quality of these efforts need to be developed. Opening up archives of already collected field boundary information would also add to our knowledge. It is likely that all of these methods would play a role in improving information on where crops are grown. OpenStreetMap, a free, editable map of the whole world that is being built by volunteers has shown that a community of mappers using a combination of approaches can be incredibly successful in changing the way we use and access important geo-information for everyday life. What would it take to make an OpenFieldMap? Does ITC have a role to play in a community whose aim would be to enable the information in the pixel to be linked to the management of the plot anywhere in the world?

There is a need for better information on when crops are grown. The production of food and forage crops is linked to seasonal and annual variation in weather and water supply, and capturing these spatio-temporal patterns of production implicitly provides information on supply as well. Cropping calendars are highly dynamic [50] and reflect farmers’ changing ability to use
their natural, human, economic and technological resources. Again, the increasing access to high frequency observations is an opportunity to develop methods to monitor not just cropland or land surface phenology, but to be much more specific about the seasonal progression of crop growth. Building on the department’s expertise in extracting valuable information on the physical characteristics of crops and forages at key growth stages would support better forecasts of production and supply, and feed into models that simulate the use of ecosystem services, the impact of pests and diseases, crop growth and the impact of weather anomalies such as drought in the GIACIS and IBLI public-private-partnership projects.

There is a need for better information on how much crops are grown. While area and seasonality information are important, the sectors of the economy and government involved with food supply, markets, trade and insurance all require reliable production and yield information. There is scope to derive and validate the most reliable remote sensing parameters related to crop yield and biomass that can be used directly or indirectly to estimate and forecast production. Going back to the need for local solutions, bring such estimates down towards field level will directly support the need to better understand the spatial and temporal variability in yield and the underlying causes of this variability such as yield limiting factors (nutrient and water availability for example) and yield reducing factors (pests and diseases). Explaining this variability is essential for guiding more sustainable production that meets demand but also reduces the impact of agriculture on wildlife, habitats, soil and water resources.

There is a need for better information on how crops are grown. There is a strong link here between remote sensing and field and farmer surveys that capture essential and complementary information on management and constraints that simply cannot be seen from our “eyes in the sky”. The increasing processing and sensor capability of mobile phones, driven by user demand for multimedia, games and other entertainment, and the ease of app development and distribution means that they have become low cost, powerful tools for rapid ground data collection and data sharing at scale. The Internet of Things promises unprecedented interconnectivity between devices for monitoring and information sharing, though protocols and governance for that still need to be agreed upon and it is still unclear how this revolution in connectivity and information sharing will impact society. Smart integration of ground and air/space based observations is required for better spatial and temporal understanding of crop management and crop health. Looking at potential epidemics and actual losses from pests and diseases, requires a link between parameterised models that simulate the potential and actual losses to spatial information on crop production situations (the where, why and how of crops) and field based observations of crop health [33]. Demonstrating that we can provide reliable, timely and accurate estimates of yield and crop health is essential if spatial science is to have a role to play in generating the much needed improvement in agricultural production information.

While the research directions above have all focused on the production of food and the resources required for that production, I have always been interested in access to food and access to resources in general. Access to food can be explored by looking at the time or effort required for
people to travel from A to B (Figure 15), to obtain food, and by other measures as well [8]. Although ‘food miles’ – the distance food travels between production and consumption – is under the microscope, most food produced in Asia and Africa is consumed locally, partially because of limitations in transport and infrastructure. Hence accessibility can be used – for example - to assess the availability of nutritious food within a given area, thus identifying the rate limiting nutrients in the food supply of a given population. Understanding the spatial patterns of locally available calories and nutrients in relation to population and infrastructure would provide guidance for policy and investment to support food security and poverty reduction.

Figure 15 Accessibility on a global scale, connecting people with places. Land based travel time in hours/days to cities and shipping lanes [51]. But where do people lack access to sufficient quality and quantity of food and what are the options to address that?

Agricultural land, especially the most favourable and productive land is concentrated around our cities, it is one of the reasons why cities are where they are. Urban growth is resulting in high pressure for land use conversion, pushing agriculture into possibly less favourable areas and leading to the conversion of land from natural systems to agriculture (Figure 16). Accessibility is a useful spatial framework to look at these pressures on land use conversion.

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4 Food miles get a lot of attention, but our impact on climate change and the environment in general is influenced more by what we eat and how it was grown rather than where the food came from [53].
Land cover patterns around cities
Travel time zones around a city can be used to define regions where particular economic activities are likely to take place. Almost 60% of all cultivated land is within two hours of a city. As urban areas expand, there is huge pressure to convert agricultural land to urban uses, and to convert more distant forests, grasslands and shrublands to agriculture. These patterns of land use around urban areas mirror one of the most important models of economic geography, Johann Heinrich von Thünen’s model of The Isolated State, which links transport costs to land value.

Figure 16 Agricultural land and production is concentrated around our cities [51]. Are these patterns changing, where will change happen and what are the implications?

While the food security and agriculture theme sits within the knowledge domain of natural resources in ITC and I have outlined specific research areas that I want to focus on, one of the real strengths of ITC is synergy for societal impact whereby some of the biggest challenges can only be addressed by combined efforts. The supply of food is closely linked to water availability, climate, land policy and natural hazards while the demand for healthy and nutritious food is increasingly coming from rapid urban growth in many countries. The science and technology of earth observation and geo-information provide us with the basis for understanding all those processes and inter-linkages. I look forward to finding some of those synergies and identifying opportunities to collaborate in the faculty, in the university and with national and international partners.

**Education** If I look at education in the Natural Resources Department, we are certainly active in providing students with the opportunity to map, monitor and model aspects of agriculture. This is placed within the wider vision of sustainable natural resource management (NRM) so that students can assess and balance food security with the demands for resources from other sectors. We also offer short courses and advanced topics with a specific focus on food security and agriculture. But I feel that food security should be more visible within our education than it currently is. This may only be a matter of marketing. Or perhaps because there has not been a full time chair appointment in agriculture in the department for some time! Nevertheless with colleagues in the department I am taking a critical look to determine if:

- food security is adequately represented in the curriculum,
- the supply meets the demand, would we attract more students if food security was more visible, while maintaining the balance across our other themes,
- the continuous process of curriculum material (re)development can slowly introduce modules with a stronger food security theme.

I particularly look at the growing demand from agencies with the mandate to monitor and measure agricultural production. It is only one aspect of food security, but with increasing need
to incorporate geo-spatial data into crop assessments and agricultural statistics, there is a niche
to provide the education and training on appropriate remote sensing and GIS techniques to
support that. This is nicely complemented by the research on the most robust ways to do this.

It is also interesting to note the growth in the number of MSc programs around the world that
focus on food security, although none seem to do so through a spatial lens. Again this suggests
to me that raising the profile of agriculture and food security as a theme within our NRM course
is likely to attract students.

**People** To achieve any of those ambitions in research and education means giving people the
space to grow. I particularly like Google’s succinct talent philosophy “find them, grow them, and
keep them” and while ITC has already found a large pool of talent, part of my aim is to further
grow research and education in food security which can only happen by giving current and future
staff the space to do that, and I appreciate the support of the Dean and the department for
achieving that aim. It also means growing our collaborations and I am keen to maintain and
extend links with colleagues here in the Netherlands, in the CGIAR network and beyond.

**We all need space to grow** ITC is growing, food security remains high on national and
international agendas and geo-information science is playing a greater role in society than ever
before. There is an unprecedented amount of spatial information available. Our role is to enable
society to make the best use of it to meet its needs. Helping to shape and grow the research and
education capacity in food security and spatial agriculture at ITC is an exciting prospect but is not
something to be attempted on an empty stomach and I hope you will join me for some food and
drink after the lecture.

*Ik heb gezegd.*
Acknowledgements

I would like conclude by thanking the people who have given me the personal and professional space to grow.

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