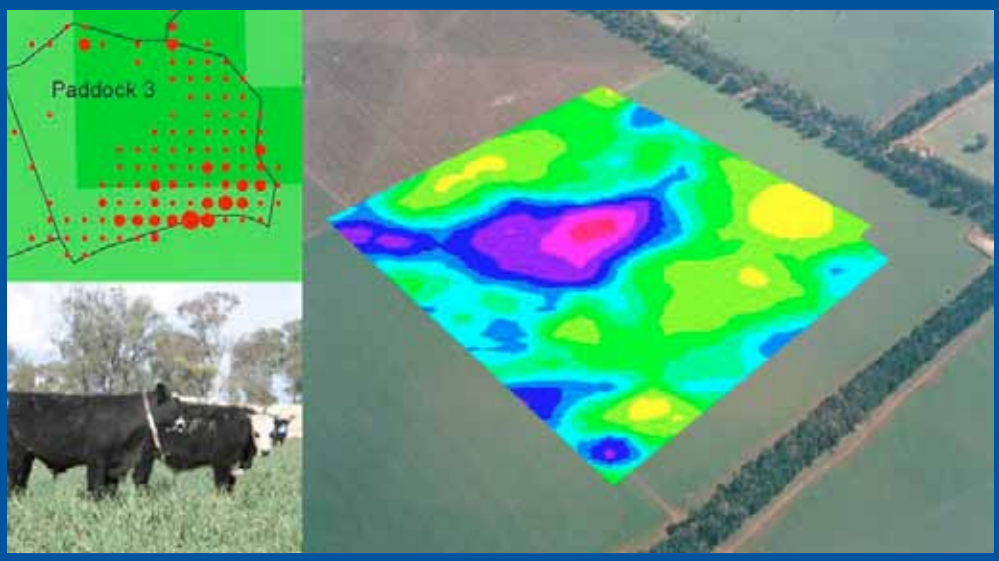
International Specialised Skills Institute

Understanding Land Use Patterns by Livestock



Dr Robin Dobos

AgriFood Skills International Fellowship

Fellowship funded by AgriFood Skills Australia

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Executive Summary

There has been an increase in the availability of low-cost animal activity sensors globally. This means that Australian grazing livestock managers are being exposed to this technology and it is important to determine how these sensors can be best utilised. These technologies have the potential to inform the livestock manager not only of the location of animals within the paddock but also potentially why they are where they are. Such technologies also have the potential to improve our understanding of how the grazing animal interacts with its environment and to improve the sustainability of grazing livestock systems. It is important that research using sensor technology is encouraged so that livestock managers are able to maximise the benefits and improve production efficiency at pasture.

The Precision Livestock Farming (PLF) unit within the University of New England's Precision Agriculture Research Group (PARG) and in collaboration with NSW Department of Primary Industries is conducting research to determine how grazing livestock managers within temperate climate zones can best apply these technologies. By improving our understanding of how to apply these sensors on-farm through research studies, the grazing livestock manager can be better informed of how the pasture resource is being utilised and how to use these technologies to make better decisions. However, there are a number of skill deficiencies within Australia.

The Fellow identified the following skill deficiencies that were required to be addressed to enable an improved understanding of how grazing livestock interact with their environment:

- Gain knowledge in the use of statistical and modelling software to analyse GPS data from livestock.
- Achieve specific skills in using these techniques by analysing livestock research data.
- Investigate implementation of analytical methodology into DSTs to make better informed decisions on animal welfare and resource allocation.
- Play a leading role in disseminating knowledge on how to use these statistical and modelling techniques to other Australian scientists utilising a Global Positioning System (GPS) for both free-range and livestock purposes.

The skills and knowledge deficiencies outlined above were partially addressed by the Fellow visiting scientists involved in grazing livestock research using animal activity sensors within the UK and Israel. These scientists have many years of experience investigating how grazing animals interact with their environment using animal activity sensors such as GPS sensors.

Scientists in the UK and Israel have utilised animal activity sensors in a number of ways. These include:

- Determining the location of animals in both private and public grazing lands.
- Predicting animal behaviour within these areas, such as grazing, resting and travelling.
- Understanding animal health and welfare, for example through shelter use and predation.

The Fellow was also able to attend an international scientific symposium, AGRI-SENSING 2011, in Israel to present his current research and was able to discuss research objectives using sensor technology with a broader audience.

The discussions with UK and Israeli scientists found that there are issues with experimental design and analysis that have still not been resolved. An important data collection issue is the synchronisation of human observation with GPS locations. Statistical analysis techniques have been developed from the wildlife and endangered species research but it is not known how relevant these are to the more controlled grazing situations with domesticated livestock.

The knowledge gained from the Fellow's visit will benefit all levels of government, industry and especially educational institutions and their students. The Fellow recommends the following actions:

- Government and industry to increase financial support of research and analysis using animal activity sensors within the Australian grazing livestock industries.
- Federal Government to develop an exchange program between Israeli and Australian scientists who are undertaking research investigations using animal activity sensors to encourage an interchange of ideas and expertise.
- Government and industry to fund organisations that encourage the use of animal activity sensor technologies to improve the understanding of land use patterns by grazing livestock in both private and public areas.
- Education institutions to encourage year 12 agriculture students to undertake projects using animal activity sensors.
- Higher education institutions to incorporate animal activity technology in undergraduate animal science and similar degrees.

The Fellow has been invited to collaborate with many of the scientists visited, especially the Israeli group. This would be enhanced by a program funded by the Federal Government encouraging scientific interchange with Israel in this area.

Research investigations using animal activity sensors to understand land use patterns in livestock are still being developed and as more investigations are conducted, better statistical procedures will also be developed. The PLF unit within PARG has recognised this deficiency by collaborating with a spatial statistics expert. However, as this is an expanding area of research more is required.

A common theme that was noted during the Fellow's discussions was the need to improve our understanding of how the grazing animal interacts with its environment. Included within this is the need to investigate more about production efficiency, as producers are being asked to *"produce more with less".*

Table of Contents

Abbreviations/Acronyms

AMS	Animal and Microbial Sciences
BBSRC	Biotechnology and Biological Sciences Research Council
CAP	Common Agricultural Policy
CO_2	Carbon dioxide
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DA	Dairy Australia
DEFRA	Department of Environment, Food and Rural Affairs
DST	Decision Support Tool (in this case computer software)
EE	energy expenditure
EU	European Union
GPS	Global Positioning System
H^+ ion	General name referring to the positive ion of hydrogen
H^+ sink	Excess H^+ ions utilised in another biochemical process
h	hour
ha	hectare
HP	heat production
HR	heart rate
IBERS	Institute of Biological, Environmental and Rural Sciences
LIDAR	Light Detection And Ranging
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolisable Energy
MEI	Metabolisable Energy Intake
MLA	Meat and Livestock Australia
NDVI	Normalised Difference Vegetation Index
NIRS	Near Infrared Spectrophotometry

Abbreviations/Acronyms

NSW DPI	New South Wales Department of Primary Industries
O_2	Oxygen
PARG	Precision Agriculture Research Group
PICSE	Primary Industries Centre for Secondary Education
PLF	Precision Livestock Farming
r^2	Coefficient of determination and is a measure of goodness of fit of the prediction model e.g. as used in linear regression
RAF	Royal Air Force
RE	Retained Energy
RFI	Residual Feed Intake
SAC	Scottish Agricultural College
THI	Temperature Humidity Index
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UNE	University of New England
VO_2	Maximal oxygen consumption
£	Great Britain pounds
~	approximately
±	plus or minus

Definitions

Animal-pasture interface

The dynamic interchange between the herbivore and the ecosystem.

BrightAnimal

An European Union (EU) Framework 7 Co-ordination and Support Action Project looking at Precision Livestock Farming.

Coccidiostat

A chemical added to animal feed to retard the life cycle or reduce the population of pathogenic coccidian such that the disease is minimised and the host develops immunity.

Condition score

A management tool for evaluating the energy reserves of an animal.

Design

Design is problem setting and problem solving. Design is a fundamental economic and business tool. It is embedded in every aspect of commerce and industry and adds high value to any service or product—in business, government, education and training, and the community in general.[1]

Digesta kinetics

Rate of digestion and passage of feed by ruminant livestock.

Energy expenditure

The amount of energy (megajoules) that an animal uses to breathe, circulate blood, digest food, and be physically active.

Faecal NIRS

The analysis of faeces by Near Infrared Spectrophotometry (NIRS).

FutureDairy

An industry-driven, national project investigating alternative systems to increase on-farm productivity and innovations that have the greatest potential to impact on farmers' economic wellbeing and lifestyle.

Heat production

The amount of heat produced during an animal's daily activities.

Innovation

Creating and meeting new needs with new technical and design styles. (New realities of lifestyle).[2]

***In sacco* degradation**

A method of determining degradation of ruminants feeds in the rumen using special nylon bags.

In vitro degradation

A method of determining degradation of ruminant feeds outside the rumen using donor fluid.

Metabolisable Energy

The energy available from feed used by the ruminant for maintenance, milk production, activity, pregnancy and weight gain.

Residual feed intake

The difference between actual feed intake and that predicted on the basis of requirements for production and maintenance of body weight.

Retained energy

The amount of energy retained in the animal as meat, milk and wool.

Skill deficiency

A skill deficiency is where a demand for labour has not been recognised and training is unavailable in Australian education institutions. This arises where skills are acquired on-the-job, gleaned from published material or from working and/or studying overseas.[3]

There may be individuals or individual firms that have these capabilities. However, individuals in the main do not share their capabilities, but rather keep the intellectual property to themselves. Over time these individuals retire and pass away. Firms likewise come and go.

Sustainability

The ISS Institute follows the United Nations for Non-Governmental Organisations' definition on sustainability: *"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".*[4]

Temperature Humidity Index

The combination of temperature and humidity that is a measure of the degree of discomfort experienced by an animal in warm weather.

Acknowledgements

Dr Robin Dobos would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide him throughout the Fellowship program.

Awarding Body – International Specialised Skills Institute (ISS Institute)

The International Specialised Skills Institute Inc is an independent, national organisation that for over two decades has worked with Australian governments, industry and education institutions to enable individuals to gain enhanced skills and experience in traditional trades, professions and leading-edge technologies.

At the heart of the ISS Institute are our Fellows. Under the **Overseas Applied Research Fellowship Program** the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

1. Preparing a detailed report for distribution to government departments, industry and educational institutions.
2. Recommending improvements to accredited educational courses.
3. Delivering training activities including workshops, conferences and forums.

Over 180 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas conduct training activities and events. To date, 22 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010':

> Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change.
>
> International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills, but also multiple and higher level skills and qualifications. Deepening skills across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills across a range of industries and occupations.[5]

In this context, the ISS Institute works with Fellows, industry and government to identify specific skills in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional practice, which they then share with their peers, industry and government upon their return. This is the focus of the ISS Institute's work.

For further information on our Fellows and our work see www.issinstitute.org.au.

Fellowship Sponsor

AgriFood Skills Australia is the Industry Skills Council for the agrifood industry: the rural and related industries, food processing (including beverages, wine and pharmaceuticals), meat, seafood and racing. Dr Dobos would like to thank them for providing funding support for this Fellowship.

Supporters

The Fellow acknowledges the invaluable support and encouragement of the following organisations:

- AgriFood Skills Australia, Canberra
- NSW Department of Primary Industries (NSW DPI)
- University of New England (UNE).

The Fellow also acknowledges the following persons for their invaluable support and encouragement:

- Dr Paul Arthur, Research Leader, Animal Genetics, NSW DPI
- Dr Alison Bowman, Director Productivity and Food Security Research, NSW DPI
- Professor David Lamb, Leader, Precision Agriculture Research Group (PARG), University of New England
- Dr Mark Trotter Research Lecturer, PARG, UNE.

Employer Support

The Fellow acknowledges the support of his employer, NSW DPI.

Organisations Impacted by the Fellowship

- AgriFood Skills Australia, Canberra
- Angus Society of Australia
- Clyde Agriculture
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Cooperative Research Centre (CRC) for Spatial Information
- CRC for Beef Genetics Technologies
- CRC for Sheep Industry Innovation
- Dairy Australia
- Department of Agriculture, Fisheries and Forestry, Canberra
- Department of Agriculture and Food, Western Australia
- Department of Employment, Economic Development and Innovation, Queensland
- Department of Primary Industries, Victoria
- Ebor Beef
- FutureDairy

- Meat and Livestock Australia
- Milne AgriGroup
- NSW DPI
- NSW Primary Industries Education Foundation
- Primary Industries Centre for Secondary Education
- Primary Industries and Resources, South Australia
- South Australian Research and Development Institute
- Sundown Pastoral
- Tasmanian Institute of Agricultural Research
- Twynam Agriculture
- Victorian Department of Primary Industries
- University of New England, Precision Agriculture Research Group

About the Fellow

Name: Dr Robin Christopher Dobos

Employment

- Research Scientist, Animal Systems Modelling and Analysis, Industry & Investment NSW, Beef Industry Centre of Excellence, Armidale, NSW 2350

Qualifications

- PhD, University of New England, 2008
- Master Science, University of Sydney, 2000
- Grad. Dipl. Appl. Stats., University of South Australia, 1987
- Bachelor Agricultural Science, University of Adelaide, 1979

Memberships

- Australian Society of Animal Production (1990–current)
- Australian Delphi Users Group (2007–2008)
- Australian Institute of Agricultural Scientists and Technologist (1979–1999)

Brief Biography

Dr Dobos began his career as a Technical Officer with the South Australian Department of Agriculture in 1978 at Northfield Research Station. His role was to test introduced *Medicago* species and develop new cultivars suitable for rotational cropping systems in the South Australian environment. In 1981 Dr Dobos was appointed as a Research Scientist with the Dairy Research Unit at Northfield Research Centre, where his main task was to conduct investigations into heifer growth and development, particularly the effect of prepubertal growth rate on mammary gland development.

In April 1984 he was appointed Dairy Research Scientist with the Tasmanian Department of Agriculture at Elliot Research Station, conducting a number of research studies on dairy cow nutrition, heifer growth and development, grazing management and Decision Support Tool (DST) development. It was during this time that he developed his research interest into the pasture-animal interface. In August 1990, he was appointed Livestock Research Officer with NSW Agriculture at Elizabeth Macarthur Agricultural Institute, Camden. During this time Dr Dobos led a number of research teams. These included the development of *Beef-N-Omics*, a DST for beef breeding enterprises (second prize at the NSW Royal Agricultural Society, 1992), investigating dairy heifer growth and development, development of DSTs known as *Higro* (heifer growth management) and *FeedPlan* (feed planning for dairy farms).

In 1997 Dr Dobos relocated to the Beef Industry Centre of Excellence in Armidale, NSW developing the DST called *FeedSmart* for the Australian dairy industry in 2005 and in 2006 upgraded *Beef-N-Omics* to a Windows version. This DST is now part of NSW DPI ProFarm© educational program for beef cattle managers. His PhD thesis investigated aspects of the pasture-animal interface, in particular grazing animal behaviour and lead to his involvement with PARG at UNE. Within this group he supervises and conducts research investigations into correlating movement metrics with animal locations obtained using GPS tracking devices to improve landscape utilisation by grazing sheep, beef and dairy cattle. He has also supervised a number of higher degree research students at UNE.

During his career Dr Dobos has published more than 20 scientific articles, three book chapters, two theses, three software user manuals and a number of conference papers.

Aims of the Fellowship Program

The aim of the Fellowship was to establish fundamental knowledge of current methodologies on analysing land use patterns in livestock from spatio-temporal data collected using GPS loggers and how best to incorporate these into decision making tools.

This was achieved by meeting with researchers on animal movement analysis and modelling.

Benefit: Understanding how livestock move within their grazing area will enable livestock managers to develop and implement more sustainable feeding management systems.

Skills Deficiencies

Resource allocation by livestock managers has become a vital strategy to ensure sustainable use of limited grazing land to produce meat, milk and wool. Understanding how the animal interacts with its environment and its herd-mates is important in achieving high utilisation of the grazing area while ensuring sustainable management of the resources. It also has implications for animal welfare. GPS loggers on selected animals within the flock or herd will help scientists determine important factors that can influence sustainable resource allocation. Livestock managers can then utilise this information to make better decisions to ensure sustainable resource allocation within their enterprises.

The major skills deficiencies identified were:

- gain knowledge in the use of statistical and modelling software to analyse GPS data from livestock;
- achieve specific skills in using these techniques by analysing livestock research data;
- investigate implementation of analytical methodology into DSTs to make better informed decisions on animal welfare and resource allocation; and
- play a leading role in disseminating knowledge on how to use these statistical and modelling techniques to other Australian scientists utilising GPS for both free-range and livestock purposes.

Benefits

Improving the understanding of land use patterns of livestock using these analytical techniques will benefit Australian scientists and livestock managers by:

- improved understanding the interactions of the animal with its environment;
- improved allocation of feed resources for the production of meat, milk and wool;
- improved understanding of issues related to animal welfare e.g. shade, shelter belt use, birth event, oestrus; and
- improved knowledge of usefulness and application of these statistical and modelling techniques.

The Australian Context

The use of GPS tracking devices to understand and improve land use patterns by domestic grazing livestock is a relatively new research area in Australia. Most of the research with grazing livestock using these technologies has been conducted overseas and, while research has been conducted in rangeland areas of northern Australia, there are differences in climate and pasture species to that of temperate grazing zones. There is limited knowledge on how animal activity sensors can be applied to the smaller paddocks utilised under more controlled grazing management strategies within temperate climate zones.

SWOT Analysis

Strengths

- Grazing offers low cost feeding management of livestock
- Improvements in productivity and sustainability in grazing livestock industries
- Large literature available on previous techniques to assess land use patterns by grazing livestock and wildlife
- DSTs are available that integrate knowledge to improve livestock industry natural resource management

Weaknesses

- No easy-to-use livestock management tools incorporating animal tracking data
- Limited research and development correlating grazing behaviour and animal movement metrics
- Limited knowledge on experimental design

Opportunities

- Increase knowledge and understanding of land use patterns in livestock using tracking devices
- International collaboration in research and development
- Research and development into DSTs
- Improve adaptation to climate variability, especially managing livestock during drought
- Design experiments to investigate correlations between animal movement metrics and grazing behaviour
- Educate livestock managers and students on the benefits of using tracking devices to understand how grazing livestock interact with their environment

Threats

- Pressure from lobby groups to governments
- Inaccurate press reports on natural resource management by livestock industries

Identifying the Skills Deficiencies

Skills Deficiency 1

Knowledge in the use of statistical and modelling software to analyse GPS data from domesticated grazing livestock.

Background/Process

- Meet with researchers that have investigated the use of GPS and other sensors to determine intake and behaviour of grazing livestock.
- Discuss use of statistical and modelling software to analyse spatio-temporal GPS data. A large knowledge base exists for wildlife and endangered species but are the same statistical techniques and models appropriate for grazing livestock?
- GPS loggers collect large amounts data on the location of the animal in space and time. Therefore, meet with researchers to discuss the best ways to store such data
- Cost of GPS loggers for researchers and managers of grazing livestock has been substantially reduced. Therefore, what is the best approach for applied research into how best to utilise the GPS loggers for landscape utilisation decisions?

Outcome: Design and analysis of experiments to investigate correlations between grazing behaviour and animal movement metrics using livestock tracking devices such as GPS and other sensors for activity.

Skills Deficiency 2

Achieve specific skills in the use of appropriate statistical and modelling techniques by analysing livestock research data.

Background/Process: Better understand the analytical methods by using data collected from research studies conducted by PARG at UNE will be used. This will enable rapid learning of the techniques and the software.

Outcome: Analysis of spatio-temporal data collected by PARG.

Skills Deficiency 3

Investigate the implementation of analytical methodology into DSTs to make better informed decisions on animal welfare and resource allocation.

Background/Process: To improve sustainable resource allocation using GPS loggers on livestock, analytical methods need to be incorporated into DSTs. These tools are often available on computers. At present there are no livestock DSTs that incorporate such analyses in their decision rules.

Outcome: Liaise with collaborators, AgLabs, to help in incorporating methods into DSTs.

Skills Deficiency 4

Disseminate knowledge on how to use these statistical and modelling techniques to other Australian scientists utilising GPS to track grazing livestock.

Background/Process: What is learned will be made available to an extensive network of other research institutions through the Precision Livestock Research Alliance and the 2nd Australian and New Zealand Spatially Enabled Livestock Management Symposium to be held in Brisbane in September 2011.

Outcome: Submit abstract for 2nd Symposium.

The International Experience

Destination: Harper Adams University College

Location

Shropshire, England

Contacts

- Dr Jim Huntington, Lecturer
- Dr Robert Wilkinson, Principal Lecturer
- Professor Liam Sinclair, Professor of Animal Science
- Dr Mark Rutter, Associate Head of Department, Head of Animal Health and Welfare

Objectives

The main objective was to meet with Dr Mark Rutter to learn about the use of GPS and other sensors investigating grazing behaviour and intake. As the Fellow has expertise in ruminant nutrition and modelling, Dr Rutter allocated time for discussions with colleagues. Ruminant nutrition and grazing behaviour are closely linked; it was, therefore, opportune to discuss the research being conducted at Harper Adams.

a. Dr Jim Huntington

- In vitro digestion of feed by ruminants
- Development of anaerobic digesters for the disposal of fallen livestock and food waste to generate energy

b. Dr Robert Wilkinson

- Dnergy and protein interactions in ruminants
- Production and utilisation of alternative forages
- Manipulation of fatty acid composition of ruminant products

c. Professor Liam Sinclair

- Dairy cow nutrition and metabolism
- Rumen metabolism and fatty acid biohydrogenation
- Manipulation of the polyunsaturated and conjugated linoleic acid content of milk and meat

d. Dr Mark Rutter

- Animal preferences, including evolutionary drivers to their use in assessment of animal welfare
- GPS and other sensors to determine welfare, behaviour and intake of grazing livestock and hence land use patterns

Outcomes

a. Dr Jim Huntington

Discussions began with Dr Huntington who showed the Fellow laboratory facilities where in vitro fermenters were being used to determine fermentation characteristics of various feeds available for livestock. Dr Huntington has expertise in determination of fermentation characteristics of various feeds utilised by ruminants. His seminal paper, Huntington and Givens (1995), has so far been cited by 116 other researchers. Current research includes screening feeds for methane production, using in vitro fermenters based on the technique developed by Cone et al. (1994). These fermenters can be used without the need for CO_2 bubbling, a major limitation in some in vitro systems.

Dr Huntington is also a key collaborator on a project to test the viability of anaerobic digesters to dispose of fallen livestock and food waste to generate energy. The aims are to help regional food businesses cut their food waste disposal costs and to enable farmers to dispose of fallen livestock in a safe manner. At this stage, results indicate that pathogens such as *E. coli*, *Salmonella tiferium*, and *Clostridium frevinges* can be reduced using the anaerobic digesters.

For those who wish to find out more detail about the anaerobic digester, the following website is recommended reading: http://www.harper-adams.ac.uk/facilities/anaerobic-digester.cfm

b. Dr Robert Wilkinson

Dr Wilkinson showed the Fellow more laboratories as well as animal facilities. The laboratories were set up to analyse various chemical and biochemical aspects of feed and animal samples. The animal facilities include the Harper Adams pig unit, which was established in 1998, and this unit was upgraded in 2004 with additional straw accommodation. In 2007 the dry sow and lactation buildings were added, increasing the herd capacity to 240 sows.

There is also a beef unit where dairy-bred bull calves from the 380 head dairy herd (see later) are finished intensively to a slaughter age of 12–15 months. Recently, the college agreed to tenancy of 178 ha of mixed farmland near Telford. This area will be partially utilised to grow out bull calves under a semi-intensive beef system to supply beef year-round to the Harper Adams catering department.

The sheep unit at Harper Adams functions as a research and development facility, for education and demonstration and for commercial viability. The ewes are all Suffolk x North of England mules. Ram breeds utilised include Texel and the Charolaise. Recent experimental work has included evaluation of fatty acid supplementation of pregnant and lactating ewes, evaluation of organic minerals, evaluation of garlic as a coccidiostat in lamb diets and the effect of supplemental zinc on the performance of ewes and lambs.

c. Professor Liam Sinclair

Professor Sinclair has developed his career around improving the understanding of the relationship between energy and nitrogen transactions within the rumen. As a consequence he has investigated aspects of dairy cow nutrition and metabolism, including fatty acid biohydrogenation and the manipulation of the polyunsaturated and conjugated linoleic acid content of milk and meat.

Discussions with Professor Sinclair enabled the Fellow to enhance his understanding of the interactions between energy and nitrogen within the rumen. The Fellow is part of an international research group investigating the development of a model of rumen transactions.

d. Dr Mark Rutter

Dr Rutter was the first to use GPS loggers on domesticated grazing ruminants in 1993 (see Rutter et al. 1997). This work was a consequence of the Chernobyl nuclear accident in 1986 and investigated hill sheep grazing areas to determine which areas would need to be avoided due to high levels of radiocaesium. This study was the first to demonstrate that GPS could be used to track domestic sheep and could be used to identify home-ranges and specific areas giving rise to contaminated animals. The GPS units were placed on the back of the animal and included a jaw movement sensor (see Figure 1). Because a GPS unit in the early 1990s cost £30,000, only two were built.

Dr Rutter continued using GPS sensors on domesticated grazing ruminants to investigate aspects of grazing behaviour and intake (see Rutter (2007) for a summary). He is now an international expert in the use of GPS and other sensors to determine land use patterns and grazing behaviour in domesticated ruminants. Further research has shown the usefulness of GPS and other sensors in improving our understanding of diet selection and grazing preferences.

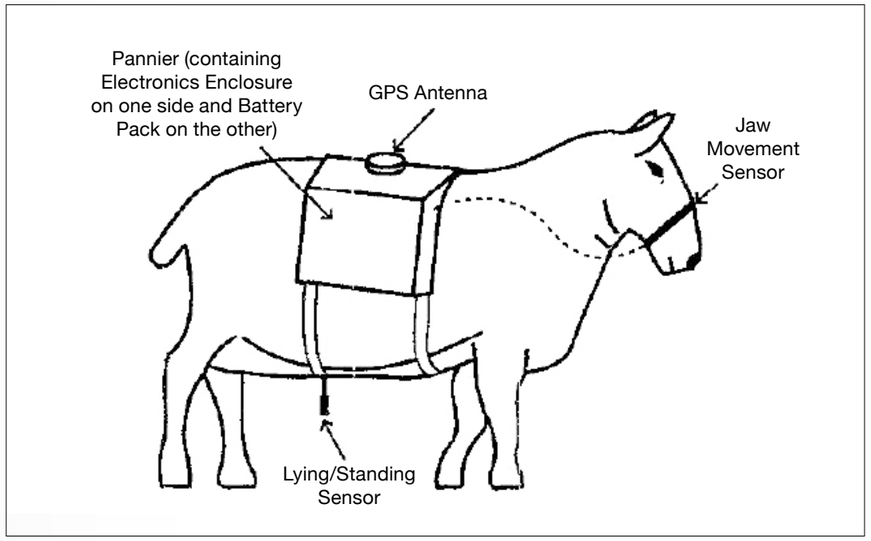

Figure 1. The approximate position of GPS and jaw movement sensors on domestic sheep in 1993 (after Rutter et al. 1997)

Use of GPS has also enabled Dr Rutter to investigate aspects of animal welfare. Dr Rutter is a member of BrightAnimal, an EU Framework 7 Co-ordination and Support Action Project looking at Precision Livestock Farming (see http://www.brightanimal.eu/).

The Fellow and Dr Rutter discussed experimental design issues when using GPS and other sensors to determine grazing behaviour, the main issue being the number of animals to be equipped with GPS sensors. Johnson and Ganskopp (2008) suggested that, depending on objectives of the experiment and the resolution chosen, the number of animals with GPS sensors will vary. If the objective is to achieve accurate assessment of resource use then longer GPS integration intervals should be avoided because of flawed spatial interpretations. Similarly, if accurate measures of travel distances are critical, then using a relatively frequent GPS recording interval is suggested.

Dr Rutter also pointed out that the length of the interval between GPS locations can be critical. If the interval is too large then the pathway travelled by the animal becomes difficult to determine (see Figure 2). Shorter time intervals are better but this will have major implications on battery life.

The next issue discussed was that of foraging behaviour. Dr Rutter has conducted many grazing behaviour experiments utilising sensors to make data acquisition of animal activity as automatic as possible (see Rutter 2007). He emphasised the need to determine the interval that will be used to collect activity data. This also meant an understanding of what activities would also be collected during this interval. In most cases, grazing, walking and resting are taken, but some investigators have included rumination, standing and lying.

When humans are recording activities, it is essential that they are calibrated so that all observers record the same activity. Dr Rutter has been involved in the development of various sensors to record animal activity. These include jaw movement sensors (Rutter et al. 1997) and acoustic sensors (Ungar and Rutter 2006). During the discussions Dr Rutter showed the Fellow video footage of how the acoustic sensors have been used in experiments designed to investigate grazing animal preferences.

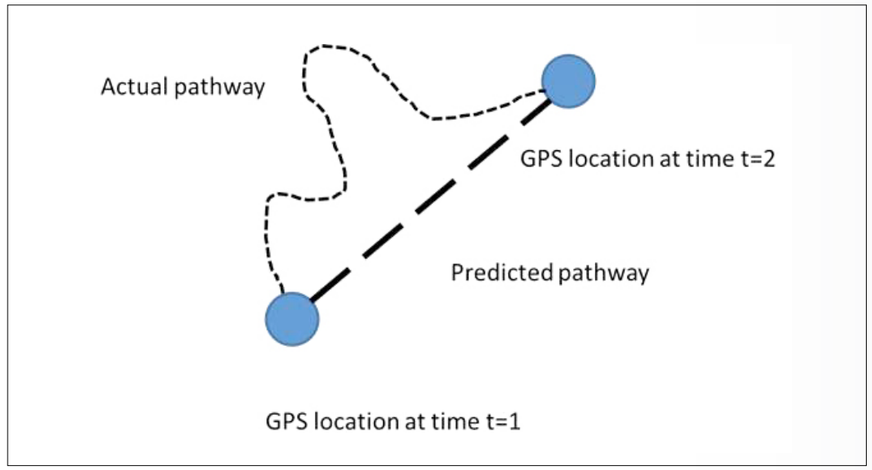

Figure 2. Representation of pathway determined from GPS locations at time t=1 and t=2. Straight dashed line is predicted pathway, while curved dash line is actual pathway between two GPS locations.

Another issue within experimental design is that of vegetation mapping. Dr Rutter emphasised the need to collect data on vegetation – quality, quantity and composition. Rutter et al. (2006) found that developing a vegetation map would require eight hours (or one working day) to map a 1.5 ha paddock with a grid of four metre intervals. This equates to 950 sample points. Decreasing the distance between sampling points increases the workload and restricts the usefulness of such an approach; therefore, a less laborious and more robust approach is required.

Figure 3. Harper Adams University College rotary dairy

Dr Rutter took the Fellow to inspect the facilities utilised for dairy and beef research (see Figures 3 and 4). During the inspection the Fellow and Dr Rutter discussed issues relating to grazing management and dairy production as well as the new robotic rotary at Elizabeth Macarthur Agricultural Institute, Camden, NSW. As the Fellow has conducted dairy research over a number of years, he was invited to inspect the dairy research unit.

Figure 4. Individual feeders in feed-shed at the Harper Adams University College dairy

Dr Rutter highlighted to the Fellow that universities in the United Kingdom (UK) are currently suffering from decreased funding, resulting in increased competition between universities. As Harper Adams specialises in agricultural-based courses, it is in a unique position, although reduction in funding will still be an issue.

Destination: Scottish Agricultural College (SAC)

Location

Sir Stephen Watson Building, Bush Estate, Penicuik

Contacts

- Dr Christina Umstatter, Grazing Biologist
- Dr Tony Waterhouse, Head – Hill and Mountain and Beef Research Centres
- Dr Bert Tolkamp, Researcher, Reader in Animal Science
- Dr Dave Ross, Researcher (Engineering)

Objectives

a. Dr Christina Umstatter

- Use of GPS tracking devices to investigate grazing and foraging behaviour
- Animal welfare measurements using sensors

b. Dr Tony Waterhouse

- Livestock farming systems, economic viability and environmental issues
- Integration of extensive livestock production with woodlands
- Interactions between labour, systems and animal welfare
- Understanding grazing impacts on biodiversity through bio-economic modelling

c. Dr Bert Tolkamp

- Modelling feeding patterns of domestic livestock

d. Dr Dave Ross

- Development of sensors for monitoring animal behaviour and welfare

Outcomes

a. Dr Christina Umstatter

Dr Umstatter's main interest is in the use of GPS tracking devices to investigate grazing and foraging behaviour of livestock. The main aim is to understand more about sustainable grazing management, nature conservation and biodiversity issues. Dr Umstatter is also interested in measuring animal welfare in extensive systems and the development of virtual fences (Umstatter 2010). Such a system could play a key role for further development of precision rangeland management tools.

Discussions focussed on what has been achieved using GPS tracking devices in relation to grazing and conservation issues. Dr Umstatter's current work focuses on a five-year project investigating grazing and foraging behaviour of three different cattle genotypes (Luing, Charolais and Aberdeen Angus x Limousin) in the uplands of Scotland. Luing are the native breed of cattle. Grazing behaviour is measured by using GPS collars on cows with calves at foot that are given free access to semi-natural grasslands on two different hills in the Pentlands during the summer.

Figure 5. The hill in the background is the type of country that is being used to research interactions between grazing behaviour and conservation

The locational data is then linked to vegetation maps. Body weight, condition score data is collected and faecal samples are taken to investigate the type of vegetation used by the animals. The aim is to provide information for grazing management decisions. Figure 5 highlights the type of country that Dr Umstatter has been conducting her research in.

A key point from these discussions was the need to develop vegetation maps in conjunction with GPS location and animal behaviour data. The issue of animal movement metrics and animal behaviour was also discussed. It would appear that this is the limiting factor in developing DSTs that intend to use GPS location information.

b. Dr Tony Waterhouse

Dr Waterhouse is Head of the Hill and Mountain and Beef Research Centres at SAC, and his research focuses on livestock systems, with a particular focus on the uplands. He currently leads programs of work that investigate the interactions between livestock farming systems, economic viability and environmental issues. Dr Waterhouse has overall management responsibility for SAC's upland farms of Kirkton/Auchtertyre at Crianlarich and the Bush Farms in the Pentland Hills near Edinburgh.

Dr Waterhouse has also been involved in practical research that has sought to improve returns to sheep producers via genetic improvement, improved nutrition and healthcare. In recent research, he has considered how different elements of extensive livestock production might benefit from integration with woodlands and how labour, systems and animal welfare interact. He has a strong background in the understanding of grazing impacts on biodiversity related issues and has utilised bio-economic modelling.

Figure 6. Large calorimetric chamber designed to measure gas production in cattle at the Scottish Agricultural College (SAC), Sir Stephen Watson Building, Bush Estate, Penicuik

His current research is on measuring greenhouse gas emissions in beef and sheep systems by linking together grazing studies through more intensive measurement protocols in controlled environments to estimate the impact within full livestock systems and whole farms. Much of his research is part of participative research, usually with land managers and farmers, based around the premise that the influence of people is of greater significance than the traditional view of animal science being about animals, health and nutrition.

The Fellow inspected new facilities developed to better understand the interactions between nutrition and methane production. These facilities include chambers for measuring gas production from livestock while consuming various nutrients (see Figure 6).

Electronic feeders, designed to measure gas production from individual livestock as they feed, are also being used to help select animals for Residual Feed Intake (RFI) (see Figure 7).

Figure 7. Individual feeders developed to measure gas production in cattle

After inspecting the facilities, the Fellow presented a seminar to members of the SAC Bush Estate, researchers and postgraduates. The seminar highlighted the research that the Fellow has conducted and is currently conducting in the area of livestock systems.

c. Dr Bert Tolkamp

The Fellow discussed modelling feeding patterns of cattle with Dr Tolkamp, as both have published papers in this area (see Dobos and Herd 2008; Yeates et al. 2001). Dr Tolkamp has developed software suitable to investigate feeding patterns using the intervals between feeding bouts to determine patterns. The Fellow was interested if the software could be used to analyse data from grazing experiments. Dr Tolkamp was confident this could be done, but so far no data from grazing experiments has been analysed. The Fellow discussed collaborating with Dr Tolkamp to use data from both pen feeding trials for cattle selected to differ in RFI to test the models, in the first instance.

d. Dr Dave Ross

The area of development of sensor technology is moving rapidly. Dr Ross is an engineer involved in the development and manufacture of sensors for use in agricultural enterprises. At SAC the group has been developing sensors for the livestock industries. These include sensors for oestrus detection, GPS that download direct (via blue tooth), feeding behaviour and physiological status.

Dr Ross explained to the Fellow the SAC field methane detector based on laser technology (see Chagund et al. 2009). The group are working on developing a methane detector that is placed on the animal. Details were lacking due to patent and copyright issues. The group have also developed a rumen bolus to measure temperature, pressure, pH and gas content. The Fellow noted that this type of sensor is already available commercially for cattle through Kahne Ltd, New Zealand, while CSIRO Australia is developing one for sheep. Dr Ross' group has also developed sensors to assess meat quality, especially at slaughter (Prieto et al. 2010; Navajas et al. 2010; Prieto et al. 2009).

Destination: Institute of Biological, Environmental and Rural Sciences (IBERS), Aberystwyth University

Location

Plas Gogerddan, Aberystwyth, Ceredigion, Wales

Contacts

- Professor Nigel Scollan, Leader, Animal & Microbial Science
- Dr Euan Joong Kim, Research Scientist
- Dr John Moorby, Principal Investigator, Ruminant Nutrition
- Dr Mariecia Fraser, Principal Investigator, Grazing Ecology
- Dr Alan Lovatt, Research Scientist
- Mr Alan Gay, Plant Physiologist

Objectives

a. Professor Nigel Scollan
- Plant-microbial interactions
- Animal systems

b. Dr Euan Joong Kim
- Plant-based feeding strategies to reduce greenhouse gasses

c. Facility Tour
- Tour of plant breeding and dairy research units

d. Dr Jon Moorby
- Meeting diversity targets

e. Dr Mariecia Fraser
- Use of GPS in grazing ecology to meet diversity targets

f. Dr Alan Lovatt
- Use of field NIRS to determine pasture quality

g. Mr Alan Gray
- Vegetation mapping using hyperspectral imaging

Outcomes

a. Professor Nigel Scollan

The IBERS at Aberystwyth University began in the early 2000s as a result of the Ministry of Agriculture, Fisheries and Food (MAFF) becoming DEFRA. Before this, much of the research was conducted by the Institute of Grassland and Environmental Research at North Wyke. There are 300 staff with 1,200 students and an income of £24 million of which £17 million is for research. IBERS have an outcome-based structure and are focussed on delivering holistic solutions to the global grand challenges:

- living with climate change
- renewable energy
- global food and water quality
- animal and plant diseases.

Aberystwyth University offers a degree that is recognised for employment anywhere in the world.

There are three main research themes within IBERS:

- Crops – breeding and genetics
- Bio-renewables – biomass/platform chemicals
- Animals and microbes – microbial ecology (microbial metagenomics).

There are up to five microbial ecologists within the group, emphasising the need to understand the interactions between microbes and the host. Current research is focussed on lipid biohydrogenation by microbes.

Most of the research is funded by Biotechnology and Biological Sciences Research Council (BBSRC) at approximately £5 million annually and is divided among three main delivery systems:

- Basic
- Strategic
- Applied.

Within IBERS is the Animal and Microbial Science (AMS) group, which investigates the area of plant microbe rumen interactions and animal systems. Funding for the group is mainly through BBSRC.

The major research being conducted by the AMS group includes:

- Metabologenomics – the interactions between animal diet and human health
- Rumen Function – pasture utilisation, plant breeding, manipulation of rumen function, microbial biochemistry, plant-microbe-host interactions
- Animal Systems – health, environment and farm system.

There is also a small group investigating aspects of equine research, both for the stud industry and general industry issues.

b. Dr Euan Joong Kim

Dr Kim has been investigating the effects of high sugar grasses on rumen metabolism. This work has led to the project entitled 'Plant-based strategies in ruminants to decrease greenhouse gasses, particularly methane'.

The aim is to reduce greenhouse gasses produced by ruminants through investigation of new technologies and methodologies:

- inhibition of methanogens
- reduction in H^+ ion production
- providing an alternative H^+ sink
- changing the microbial population.

To achieve this Dr Kim has been applying high sugar grasses and additives, such as plant extracts, probiotics and lipids.

c. Facility Tour

In the afternoon, the Fellow was given a tour of the research facilities of the university. Major research units visited included the plant breeding unit and the dairy unit. The plant breeding unit have developed varieties of high sugar grasses that are being tested by Dr Kim as discussed above. Figure 8 shows the plant breeding plots currently being tested.

Figure 8. Plants being tested by plant breeding unit at Aberystwyth University

At the dairy unit, the herd of ~500 cows is being used to research methane. There is also a herd of ~180 organic cows and replacements. Research is being conducted to measure nitrogen and methane production from soils on the University dairy and cooperating farms. Part of this unit contains the facilities used by researchers to measure *in sacco* degradation of feeds in the rumen and also measure digesta kinetics (see Figure 9).

Figure 9. Facilities used to measure in sacco *degradation of feeds and digesta kinetics in the rumen*

Figure 10. Methane measuring chambers for sheep

During the tour, the Fellow was shown the new methane gas measuring chambers for sheep (see Figure 10). At Aberystwyth there is also a small herd of native Welsh Black cattle that are used to test how genetic selection has shifted production indicators over time (see Figure 11).

Figure 11. Native Welsh Black steer

To test hypotheses on aspects of reproductive physiology, Aberystwyth researchers have a sheep flock available that can produce multiple lambs (Figure 12). The flock is currently being used to test hypotheses relating to feed additives in the diet.

Figure 12. Highly fecund sheep flock

The Fellow is indebted to Dr Rhun Fychan, research leader of the plant breeding unit, for taking time out of his busy schedule to show the facilities.

d. Dr Jon Moorby

Recently the EU has implemented the EU Common Agricultural Policy (CAP). Originally the CAP was developed because of the food shortages shortly after the end of World War II. It has now been modified with the aim to provide farmers with a reasonable standard of living and consumers with quality food at fair prices. The way these aims are met has changed over the years. Food safety, preservation of the rural environment and value for money are now all key concepts. There is also a land-based payment that rewards farmers for being environmentally friendly.

Dr Moorby is conducting investigations comparing cattle and sheep and breeds within species on areas formerly closed for conservation. In the past the view was that domesticated livestock over-grazed sensitive areas set aside for conservation. This led to large areas of natural grassland and heath being closed to grazing. It became obvious that without some form of grazing, pernicious plants began to dominate the landscape. Therefore, research is being conducted to investigate the impact of grazing by domesticated livestock on plant biodiversity within these areas. The aim was to measure sward composition and water management. Dr Moorby is using GPS and other sensors to understand how the animals interact with their environment to determine optimum stocking rate. It was found that by grazing these areas with livestock, especially cattle, grasses returned.

In 2010, Aberystwyth University was awarded £3.9 million to conduct research into methane production from livestock. Working with teams from six other institutions across the UK, IBERS' scientists have been assessing the amount of methane being released into the atmosphere by agricultural livestock and generating data that allows more accurate estimates of emissions throughout the UK. Dr Moorby is a principal investigator on this project (see http://www.aber.ac.uk/en/ibers/research/research-news/methane-study/).

e. Dr Mariecia Fraser

Dr Fraser collaborates closely with Dr Moorby on the above projects, including the methane study. She has been investigating grazing behaviour of livestock in conservation areas using bite counters and GPS sensors. During these investigations Dr Fraser has also been studying intake and diet preference at the patch scale. One of the major restrictions on this work has been the cost of analyses and collection.

f. Dr John Clifton-Brown

Dr Clifton-Brown has used the Trimble® GPS unit in his plant breeding studies. Problems encountered included a delay in logging the position of plant from 52 cm down to 13 cm. There was also a 24 h delay for position. This GPS logger is complex to use and requires the user to have a fair bit of technical know-how. Each unit costs £8,000.

g. Dr Alan Lovatt

Dr Lovatt is a Research Scientist investigating the use of field NIR to determine the quality of pasture plants. The unit is static and requires 3-phase power. It is mainly used indoors and requires calibration.

h. Mr Alan Gay

Mr Gay is a plant physiologist with a passion for new technology. His research has led him to become involved in investigations using hyperspectral aerial imaging to create vegetation maps. Major problems occurred using satellites because of cloud cover and the research moved to the use of Unmanned Aerial Vehicle (UAV) with a Light Detection And Ranging (LIDAR) system attached.

There is a problem with using the UAV, as Aberystwyth is located near a Royal Air Force (RAF) base. Therefore, researchers have to inform RAF of their intention to use the UAV, so it isn't shot down during one of its flights.

The group has also conducted research using live video equipped with infrared and matched GPS locations with the frames from the UAV. Normalised Difference Vegetation Index (NDVI) values have been calculated. The gridding system used depends on the vegetation being studied.

Data is analysed using Definiens Professional software, which allows the user to analyse images very quickly. It can help in determining changes to the landscape both spatially and temporally.

Destinations: AGRI-SENSING 2011 Symposium – Technion, and Newe Ya'ar Research Station

Location

Haifa, Israel

Contacts

- Dr Arieh Brosh, Research Scientist, Retired
- Dr Yoav Aharoni, Research Scientist, Retired
- Dr Eugene Ungar, Researcher, Plant Sciences, Agricultural Research Organisation
- Dr Ilan Halamchi, Engineer, Robotic Milking Systems
- Dr Ariel Shabtay, Ruminant Molecular Stress Physiology
- Dr Zelman Henkin, Researcher, Range Management & Ecology, Newe Ya'ar

Objectives

a. AGRI-SENSING 2011

- Attend and present at AGRI-SENSING 2011: International Symposium on Sensing in Agriculture in Memory of Dahlia Greidinger, Technion, Haifa, Israel

b. Dr Arieh Brosh

- Measuring heart rate to determine energy expenditure in grazing livestock

c. Dr Yoav Aharoni

- Measurement of energy expenditure in grazing livestock
- Modelling digesta kinetics

d. Dr Amit Dolev

- Optimising the location of water, feeding sites and shade
- Measuring bull effectiveness using GPS

e. Dr Eugen Ungar

- Use of GPS and other sensors to determine grazing behaviour
- Design of experiments to using GPS in grazing livestock
- Comparison of sensors to measure animal activity

f. Dr Ilan Halamchi

- Design and modelling of robotic milking systems

g. Dr Ariel Shabtay

- Stress physiology and feed efficiency

h. Dr Zelman Henkin

- Rangeland management and grazing ecology

Outcomes

a. AGRI-SENSING 2011

Before leaving Australia, the Fellow submitted an abstract to *AGRI-SENSING 2011: International Symposium on Sensing in Agriculture in Memory of Dahlia Greidinger* to be held at Technion, Haifa, Israel. The abstract was accepted and the Fellow was invited to speak at the symposium (see Attachment and Dobos et al. 2011). The Fellow attended the first two days of the symposium and then met with colleagues from Newe Ya'ar Research Station over the next three days to discuss the use of sensor technology in understanding how grazing livestock interact with their environment.

Symposium presentations dealt with precision agriculture and how it can help in improving production efficiency within agriculture. Morning presentations were mainly by keynote speakers, while afternoon sessions were divided into themes. The Fellow presented on Tuesday 22 February at 1440h under the Rangelands theme.

The key presentations on day 1 were:

- Precision nutrient management
- Water stress sensing in fruit trees
- Development of nanomaterial platforms and lab-on-chip technologies
- Key advances and remaining knowledge gaps in precision agriculture
- Sensing nitrogen status in plants
- Overview of electro-magnetic methods to determine soil water content and salinity.

Themes included:

- Sensing and Control Systems
- Fertilsers and Fertility
- Soil and Water Conservation
- Orchards
- Rangelands: Grazing Behaviour and Productivity
- Field Crops
- Rangelands: Vegetation Dynamics.

The Fellow was able to meet with researchers who are investigating the use of sensors in all aspects of agricultural production. Attendance and speaking at the 'Rangelands' session enabled contact with other animal scientists, especially from Israel and the USA. The uniqueness of the research that the Fellow will be conducting in collaboration with PARG was further emphasised by these contacts. Most of the research conducted to date has been with animals grazing rangeland-type pastures. Very few studies have been conducted on temperate pastures.

b. Dr Arieh Brosh

The Fellow met with Dr Arieh Brosh at Haifa and travelled to the Newe Ya'ar research centre. Dr Brosh retired in late 2010 but hosted the Fellow on the first day. During the visit it was required of the Fellow to present a seminar highlighting Australian research on livestock systems. The presentation allowed the Fellow to make contact with other livestock researchers within the group through their individual presentations. The outcomes of these discussions are summarised below.

Measuring Energy Expenditure in Grazing Cattle

Dr Brosh's research has mainly focussed on understanding the interactions between ruminant livestock production efficiency and how the feed they consumed affected it. He has investigated ways of measuring production efficiency using remote sensors (Brosh et al. 2002). These studies involved developing a heart rate (HR) monitor and logger that is able to log data over four days every minute (see Figure 13).

Animals were assigned to either a low or high energy diet (Brosh et al. 2006). The data is downloaded after the animals are put through a crush. Dr Brosh and colleagues found a low standard error using this method. Further evaluation was conducted on dairy cows. It was found that heat load affected O_2 pulse, such that VO_2 decreased; whereas, work at Cornell University (USA) found that cold did not affect O_2 pulse.

Figure 13. PhD student at Newe Ya'ar showing the heart rate monitor 'belt' used on grazing cattle

From these studies, Dr Brosh and colleagues have developed a relationship between retained energy (RE) and metabolisable energy intake (MEI) and heat production (HP) and they have been able to relate HR with the temperature humidity index (THI). They found that skin temperature was a better measure of heat load (Aharoni et al. 2005).

Dr Brosh and colleagues are now using GPS and motion sensors to determine the relationship between animal activity and HP. These studies will improve our understanding of what factors influence production efficiency of livestock on pasture.

c. Dr Yoav Aharoni

Dr Aharoni has been retired for a number of years but is still an active participant in research at Newe Ya'ar through the supervision of postgraduate students and analysis of the experimental data. He has also been involved in many different types of research investigations and has worked on compartmental analysis of digesta kinetics and the analysis of GPS and IceTag® accelerometers data (e.g. Aharoni et al. 1999; Ungar et al. 2011).

Energy Expenditure and Efficiency in Dairy Cows

With Dr Brosh and a Masters student, Dr Aharoni is advising on experiments to determine the external and internal factors affecting energy expenditure (EE) using both dairy cows and the native cattle species, Balidi.

The Masters student has conducted research on EE in lactating dairy cows. Preliminary results indicate that increasing the temperature humidity index (THI) decreased all parameters measured, except RFI-ME, which did not change with increasing THI. Day length affected RFI-ME, whereby long days reduced EE. The student also found that RFI was best explained by residual heat production (RHP) with an $r^2 = 0.69$.

Compartmental Analysis of Digesta Kinetics

The Fellow conducts research studies into digesta kinetics of ruminants using inert markers such as Cr-EDTA and Cobalt. Dr Aharoni has expertise in using compartmental analysis to analyse this type of data (Aharoni et al. 1999). Knowledge gained from Dr Aharoni on how to conduct such analyses will benefit researchers and higher degree students in Australia.

d. Dr Amit Dolev

Optimising the Location of Water, Feeding Sites and Shade

There is an issue with water quality in the Sea of Galilee due to pollution from stray cattle drinking in the sea. Previous work conducted by the group at Newe Ya'ar using Lotek® GPS loggers found that cattle increase their frequency of visits during the summer. Therefore, an experiment was designed to determine the optimal location of water, feeding sites and shade to reduce contamination of water by cattle.

The experimental treatments were: (1) control, (2) water trough only, (3) feeding site only and (4) feeding site+water trough. The supplement used was poultry litter and cattle movements were recorded every five minutes over one week (Dolev et al. 2010).

It was found that cattle located the feeding site quickly and that grouping feeding site and water was best. The experiment also found that, depending on location, there was a large effect on spatial distribution. Dr Dolev utilised kernel home range analysis of GPS locations to determine the effectiveness of each treatment.

Measuring Effectiveness of Bulls During Mating

One of the questions often asked by cattle producers all over the world is: how effective are the bulls that are used during mating? Dr Dolev has attempted to answer this question by using GPS sensors and analysing the proximity index to determine bull effectiveness during mating. Early results indicate that GPS can be a useful tool to measure bull effectiveness during mating.

After the meetings, the Fellow met with commercial representatives from ENGS systems, including Manager, Eran Tuval. This Israeli company produces 'Track-a-Cow', a heat and movement telemetry system mainly for dairy herds. Their product has a 15-minute recording resolution and is the smallest pedometer on the market and the representatives were interested in discussing potential collaboration and use of the product in Australia.

e. Dr Eugene Ungar

Dr Ungar has published many scientific articles investigating the use of various techniques to determine factors affecting behaviour and intake of grazing livestock. These experiments have included the use of sensors to measure jaw movements, GPS and other activity sensors, as well as video and audio recordings to determine individual animal intake. He has also utilised artificial swards to determine diet selection and investigated the effect of patch depletion on bite mass. Recent studies have utilised Faecal NIRS as another method to determine intake.

Stocking rates for northern Israel are around two ha per cow and this determines production efficiency on pasture. Therefore, increasing stocking rates above this can be risky due to the large variability in the Mediterranean climate. Understanding how grazing livestock interact with their environment will help local farmers improve production efficiency. Dr Ungar is using GPS and other activity sensors to determine the factors involved.

Dr Ungar is supervising a PhD student who has found a low-cost GPS and activity sensor. This sensor is used in the recreational and sporting industries, such as monitoring athletic performance. The 'i-gotU USB GPS Travel & Sports Logger - GT-600' was developed by Mobile Action Technology Inc. (http://global.mobileaction.com/product/product_i-gotU_GT-600.jsp accessed 24 Feb 2011). The student is planning to utilise this type of unit to determine activity and spatial distribution of grazing animals.

Further discussions with Dr Ungar involved exchanging knowledge on issues with human recording of grazing activity in conjunction with use of GPS and other sensors. It was agreed that the main problem is ensuring the synchronisation between human recording and sensor data collection. Dr Ungar highlighted how his group have recorded the transition from one activity to another during the observation time. For example, if the observation time is five minutes and the animal lifts its head while grazing, is this a conclusion of the activity or merely a distraction on the animal's part? If this lifting of the head while grazing event sees the animal return to grazing then the recorder has to conclude that the activity is grazing not something else. It is also crucial to ensure the interval length is not too long. An interval length of 20 minutes may mean a number of activities are included and the recorder has to determine the dominant activity.

Research into grazing activity is now moving towards the use of a combination of activity sensors. Dr Ungar's group has recently investigated the use of GPS and IceTag® accelerometers (Ungar et al. 2011). This has raised some interesting issues when attempting to combine data to determine activity and location. Dr Ungar emphasised the importance of developing good hypotheses to test. Recent research has shown that activity data can be very useful in understanding the relationship between the animal and its environment (Ungar et al. 2011).

Determining individual intake in grazing livestock is still the ultimate goal. Dr Ungar with Dr Brosh is developing and testing a 'vocal tag' that records sounds of grazing. This is a step forward from the acoustic sensor developed in the UK with Dr Rutter.

Dr Ungar is very involved in research designed to investigate individual animal intake and hopes the use of these sensors will help researchers better understand the factors regulating intake in the grazing animal. Ultimately, the results can be utilised by livestock managers to improve the production efficiency of their grazing enterprises.

f. Dr Ilan Halamchi

The Fellow has been involved in research using automatic or robotic milking systems in collaboration with the University of Sydney at Camden, FutureDairy. This research tested robotic milking systems within a pasture-based environment. However, it was realised very early on that for automatic milking systems to be utilised under pasture-based systems in Australia, a robotic system would need to be developed to milk more than 60–80 cows in a day. In November 2010, a new robotic rotary system was launched. It is hoped that this new system will attract some dairy farmers to use robotic milking.

Dr Halamchi is an engineer with experience in robotic systems, especially dairy. He is very interested in collaborating with the FutureDairy group at Camden. His expertise is in modelling these systems and monitoring cow behaviour and movement within the system. He has designed many robotic dairy systems for European-based dairying. Dr Halamchi is also involved in modelling and designing aquaculture systems.

g. Dr Ariel Shabtay

Dr Shabtay conducts research into understanding the relationship between feed efficiency and molecular stress physiology. The Fellow was shown the facilities used for this research. The group has been studying selection of bulls early in life for feed efficiency. This involves rearing bulls from birth through to final testing. Figure 14 shows the automatic calf-feeder used during rearing.

Figure 14. Automatic calf feeder used to rear bulls during testing for feed efficiency selection

Dr Ariel Brosh developed the research focus and it is being continued by Dr Shabtay. When bull calves are weaned they are then transferred to a feeding pen designed to evaluate individual intakes using automatic feeders. The feeders measure the time spent eating and how much was eaten (Figure 15). Daily weighing of the animal after it has consumed feed is conducted automatically. The animal is electronically directed through the weighing area (Figure 16). Data is then downloaded for analysis.

Figure 15. Automatic feeders to record animal feeding patterns during feed efficiency evaluation

Figure 16. Automatic weighing of cattle during feed efficiency evaluation

Dr Shabtay is also comparing energy expenditure in native cattle, Balidi with that of more modern cattle. There are about 100 Balidi left in Israel and Dr Shabtay has developed a special breeding program to ensure this very useful genetic resource is not lost.

h. Dr Zelman Henkin

Dr Henkin's research encompasses many disciplines. He has a depth of experience in leading research teams investigating both plant and animal factors affecting the production efficiency of grazing livestock. Discussions with Dr Henkin concentrated mainly on the type of terrain and plant species available to grazing livestock in northern Israel. An area that is unique to Israel is that the research stations rely heavily on working with local farmers whose livestock graze within the stations. This has both positive and negative consequences. The positive aspects mean that the researchers can talk with the farmer about any issues and resolve them quickly. The negatives include farmer attitudes towards the research, as is the case in Australia.

The Fellow then conducted a tour of two research stations north and north-west of Newe Ya'ar that are used by Dr Henkin and his group. The research study into optimisation of water, feeding sites and shade (Dolev et al. 2010) was conducted at Karei Deshe just north of Newe Ya'ar.

The Karei Deshe Experimental Range Station is situated in the lower Galilee region, near the Jordan River and the Kinneret Lake (Sea of Galilee), lat. 32°55'N, long. 35°35'E, alt. 150m. The topography is hilly, with slopes generally less than 10%. The soils are brown basaltic protogrumosols with variable depth but seldom deeper than 60 cm and with a rock cover of about 30%. The vegetation is dominated by hemicryptophytes (forbs that have a perennial root system but lose most of the shoot during the dry summer) that include *Hordeum bulbosum* L., *Echinops* spp., *Psoralea bituminosa* L.

There are also many annual species, some of which are palatable pasture plants (*Avena sterilis* L., *Bromus* spp., *Trifoliium* spp., *Medicago* spp., and many others) while others are palatable for only short periods during the early vegetative experiment (e.g. *Scolymus maculatus* L., *Brassica nigra* L., *Echium plantagineum* L.). The rainy season begins in October–November and ends in April. The pattern of vegetative growth is strongly influenced by rainfall distribution and intensity. Mean annual precipitation (±S.D.) is 556± 169 mm, fluctuating between extremes of 322 and 761 mm. Figure 17 highlights the terrain that researchers and livestock have to contend with.

Figure 17. The terrain on Karei Deshe experimental station looking east to the River Jordan, just north of the Sea of Galilee

Dr Henkin then took the Fellow to the second experimental station, Hatal. The Hatal station is situated in the Western Galilee, about 400 meters above sea level. The climate is Mediterranean with mild winters and hot dry summers. The average rainfall is 640 mm mostly in the period November to March. Maximum daily temperatures in summer are 30–40 degrees Celsius and average relative humidity, 50–60%. The area consists of moderate to steep slopes, with 0–40% cover of limestone and dolomite rocks, between which there are pockets of terra rossa soil of very variable depth. The vegetation is dominated by oak scrub forest (*Quercus calliprinos*).

When Hatal was first used for grazing research it was covered with very thick stands of woodland. This was manually thinned to make it more accessible for livestock. The station was used for a very long term grazing experiment from 1982 until 2002 to compare heavy and moderate grazing management (Henkin et al. 2005).

Figure 18 illustrates the type of terrain being used by researchers and farmers to grow and breed cattle on the Hatal experimental station.

Figure 18. The terrain and pasture types available at the Hatal experimental station

The biggest issue in terms of pasture production in this part of Israel is a deficiency of phosphorous in the soils.

Research on both experimental stations is conducted in conjunction with local farmers. This does create an interesting set of problems. While travelling to Hatal, Dr Henkin had to be interviewed by police about a theft of some cattle from the station. Such incidences are common and can cause stress for both researchers and farmer collaborators.

Concluding Remarks

The knowledge gained from the Fellow's interaction with all contacts visited will enable the development of sound hypotheses for testing factors that affect how the grazing animal interacts with its environment. The scientists visited have many years' experience in conducting basic and applied research in this area. The new technologies that are becoming available, such as sensors to measure animal activity, pose further challenges to animal scientists investigating grazing behaviour. Understanding how best to utilise them, analyse the data collected and most importantly, asking the right questions of them, will be critical.

The experience and knowledge gained from the discussions will enable the Fellow to pass on these important aspects of how to use sensors in grazing livestock research in temperate climate zones to Australian and State Government agencies, educational institutions and other scientists. It will also help in developing the link between how to incorporate the data collected from the sensors into sound decision making using DSTs. However, more experimental studies are required as skill deficiencies still remain, especially in the area of statistical analysis of data sets from research studies utilising animal activity sensors.

A common theme that was noted during the Fellow's discussions was the need to improve our understanding of how the grazing animal interacts with its environment. Included within this is the need to investigate more about production efficiency, as producers are being asked to *"produce more with less".*

Knowledge Transfer: Applying the Outcomes

During the Fellow's visit, he presented seminars on the current state of livestock research in Australia. He focussed mainly on his research work on how the grazing animal interacts with its environment. These seminars were presented in Scotland and Israel. During the visit to Israel, the Fellow was also an invited international speaker at the AGRI-SENSING 2011 symposium.

Professional

The knowledge gained from the outcomes discussed above will allow the Fellow to improve his research capabilities and the research capabilities of the teams he works with in understanding how the grazing animal interacts with its environment. This will enable the transfer of skills to students and collaborators regarding the designing of experiments using animal activity sensors.

The interest from the scientists met with is also encouraging as they are keen to collaborate, especially Dr Rutter, Dr Umstatter, Dr Henkin and Dr Ungar. It is hoped that as a result of being a Fellow this will improve the Fellow's standing and promotion prospects within his own organisation.

Industry

Research funding in this area is limited because funding organisations, such as Dairy Australia (DA) and Meat and Livestock Australia (MLA) are still coming to terms with the application of animal activity sensor technology within their industries. The Fellow will use the experience and knowledge gained to develop better funding proposals using the scientists contacted as collaborators.

The Fellow will also be able to better communicate the technology and how it can be applied to answer research and on-farm questions. This will enable consistent and constructive interchange of ideas within this relatively new area of research.

Education

In addition, the technology advances in the area of animal activity sensors are rapid. To ensure an understanding of how this technology can be used by future animal scientists, secondary high school students need to be exposed to this technology to see what the potential is. Undergraduate courses in animal science at tertiary institutions should include some aspects of this technology within their curricula.

The Fellow has presented a seminar at the inaugural NSW Primary Industries Education Foundation Agriculture Teachers curriculum day in November 2010 titled 'Managing livestock in the 21st century – tools and concepts'. This seminar highlighted the Fellow's research studies on how the grazing animal interacts with its environment and how the rapidly advancing sensor technology area will help improve this understanding. It is hoped that from this seminar, agriculture teachers will communicate with students about the technology and some of these students will be interested in conducting projects in the future.

Recommendations

Government – Federal, State and Local

Recommendations:

- improve the science on how grazing livestock impact on conservation areas based on valid evidenced-based science using animal activity and vegetation mapping sensors;
- improve the stipend offered to higher degree research students;
- increase funding to support the creation of a specialised research and development group in precision livestock farming at UNE; and
- instigate an Israel–Australia exchange program to improve research collaboration between the two countries in this research activity.

Industry

Recommendations:

- animal industry funding organisations (e.g. MLA and DA) to increase their financial support of research studies undertaken to investigate production efficiency at pasture;
- develop a global network of scientists involved in research and development projects using animal activity sensors; and
- conduct workshops and conferences funded by industry to encourage future research using this technology.

Education and Training – University, TAFE, Schools

Recommendations:

- PARG continue its relationship with PICSE so that students at secondary school level are exposed to the technology to measure how grazing animals interact with their environment;
- encourage statistics students to become involved in analysing the data generated from spatio-temporal experiments; and
- encourage year 12 agriculture students to conduct projects using this technology.

International Specialised Skills Institute

Recommendations:

- ISS Institute and AgriFood Skills Australia to consider funding another visit to key experts in the area of data management and analysis in the near future.

Skill and knowledge deficiencies still remain in the following areas:

- How to handle the large data sets generated from use of animal activity sensors;
- Appropriate statistical analyses;
- Combining activity sensor data with on-farm decision making.

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Endnotes

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Attachments

AGRI-SENSING 2011
International Symposium on Sensing in Agriculture In Memory of Dahlia Greidinger

CORRELATING GPS MOVEMENT METRICS WITH ANIMAL BEHAVIOUR

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The continuous recording of animal activity will enhance our understanding of animal behaviour and landscape utilisation by grazing livestock. Traditionally, collection of animal behaviour data relied on manual observations which are time consuming, expensive and may be unrepresentative of the full range of behaviours. Recent advances in animal tracking technology have meant that position loggers have become more readily available. GPS or local, radio frequency-based position loggers offer great potential for improving the management of grazing livestock, however position loggers generate a large amount of data. The question then is how do livestock managers use this information to make better decisions?

With support from the Cooperative Research Centre for Spatial Information (CRCSI), the Precision Agriculture Research Group at University of New England (UNE-PARG) are investigating the use of GPS-based position loggers on grazing sheep and cattle to answer this question. The main aim is to correlate movement metrics eg velocity, distance travelled with the animals' physical environment and observed behaviour. We will then use the best metric of behaviours in models and decision support tools (DST) to help livestock managers improve feeding management decisions in variable climates.

We have tested Bayesian change point analysis of velocity to identify a change in behaviour because of lambing in pregnant grazing Merino ewes (Taylor et al. 2010). This analysis revealed a high correlation (r=0.89) between a change in average velocity and lambing occurring, suggesting that this method could be useful in identifying lambing behaviour. However, average velocities between 0500 and 100h were shown to be the most consistent, therefore potentially limiting its effectiveness. More research is required to determine whether other metrics in combination with a change in velocity may enhance this methods' effectiveness. Another metric being tested is 'home range' using minimum convex polygon and kernel distribution analysis on the same sheep data. Initial results indicate that lambing behaviour reduces the home range size significantly compared to that of ewes 7d before and 7d after lambing (Dobos unpublished).

Biomass availability and quality can limit intake by grazing animals and also affect grazing behaviour. There is a distinct diurnal pattern of grazing behaviour in ruminants and this is being used to test whether behavioural changes can be identified using position data when biomass availability and quality are modified because of grazing. The metrics being tested include velocity, distance travelled, 'home range' and movement trajectories.

From this research we hope to determine a suitable metric identifying a change in behaviour from the GPS data. Once determined, the metric(s) will be then incorporated into DST to help livestock managers improve feeding management and landscape utilisation of grazing sheep and cattle.

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