CONTENIDO DEL INFORME TÉCNICO
CONSULTORES CALIFICADOS

1. Antecedentes de la Propuesta

Título

"BASES PARA LA IMPLEMENTACION DE SISTEMAS PRODUCTIVOS PECUARIOS SUSTENTABLES EN LA ZONA CENTRO-SUR DEL CHILE"

Código

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Entidad Responsable

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Lugar de Origen del Consultor (País, Región, Ciudad, Localidad)

School of Agriculture and Wine
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Lugar (es) donde se desarrolló la Consultoría (Región, Ciudad, Localidad)

VII, VIII, IX y X Región
Curicó, Talca, Chillán, Temuco, Valdivia.
Predios vecinos a estas localidades.

Fecha de Ejecución

14 de octubre 2003 a 25 de octubre 2003.

Proponentes: presentación de acuerdo al siguiente cuadro:

Nombre	Institución/Empresa	Cargo/Actividad	Tipo Productor (si corresponde)
Daniel Troncoso Boys	Universidad Católica del Maule, Agronomía	Director Escuela de Agronomía. Académico. Area Producción Animal	
Rubén Pulido Fuenzalida	Universidad Austral de Chile	Presidente Sociedad Chilena de Producción Animal. Académico Nutrición Animal	
Sergio Hazard Torres	INIA – CRI Carillanca	Especialista en Producción de Leche	
Marcelo Doussoulin Guzmán	Universidad de Concepción, Dpto. Producción Animal	Docencia e Investigación	
Pamela Williams Salinas	Universidad Católica del Maule, Agronomía	Académico. Area Producción Animal	
Fernando García Gómez	Universidad Católica del Maule, Agronomía	Académico. Area Producción Animal	
Oscar Balocchi Leonelli	Universidad Austral de Chile	Académico Instituto de Producción Animal	

Problema a Resolver: detallar brevemente el problema que se pretendía resolver con la ejecución de la propuesta, a nivel local, regional y/o nacional.

Chile, tendiendo a un incremento en sus exportaciones de carnes rojas y lácteos, se le exige la generación de productos inocuos, generados según los estándares internacionales de calidad incluyendo la reducción del impacto ambiental y asegurar la sustentabilidad. Aunque en el país se han realizado importantes esfuerzos en esta línea, falta por desarrollar una visión sistémica de la situación, requerida para la comprensión de la interacción de las variables involucradas. Más aún, el uso de modelos de simulación como instrumento de ayuda a la resolución de problemas pecuarios es aún incipiente en Chile. Falencias se han encontrado también en la transferencia de la información y orientación de los productores por mejorar sus sistemas productivos, existiendo aún pocas iniciativas que investiguen y proyecten a los productores, las necesidades exigidas por los nuevos mercados.

El forraje es el ingrediente más económico utilizable en la alimentación animal y promueve la generación de productos cárneos y lácteos de calidad. Adicionalmente, los cultivos forrajeros juegan un rol fundamental en el desarrollo sustentable, a través de su rotación con cultivos, mejoramiento de las condiciones edáficas y manejo integrado de plagas, enfermedades y malezas. Por otra parte, los sistemas productivos varían según las distintas ecorregiones y las condiciones socioeconómicas de los agricultores, donde se desarrollan, variando las especies forrajeras utilizadas y los cultivos incluidos en la rotación de cada situación particular. Por ello, las estrategias de producción son variables, diversas y complejas de enfrentar requiriendo análisis detallados de las variables involucradas para lograr soluciones *in situ*.

La IX y X Región del país, históricamente se han proyectado como las principales regiones ganaderas del país. Sin embargo, los productores han manifestado su preocupación en cuanto al futuro de estos rubros. Actualmente surgen nuevas oportunidades para los productores a través de los tratados de libre comercio firmados. En tanto, la producción animal en la VII y VIII Región se proyecta como un rubro interesante de desarrollar, mediante la implementación de sistemas productivos integrados a las explotaciones tradicionales de estas zonas.

Mediante la propuesta se pretendía resolver, a través de la experiencia australiana y de los avances realizados por el consultor en materias de diseño de sistemas sustentables, las interrogantes de productores pecuarios e investigadores chilenos, referente a las necesidades de cambio para lograr un producto de exportación e implementación del uso de forrajeras para la obtención de carne y leche de calidad, compatibilizando sustentabilidad.

Considerando que la implementación de sistemas sustentables bajo una visión sistémica de la producción, exigen un análisis local de las variables involucradas (sistema intensivo o extensivo, alimentación, razas, clima, costos, recursos humanos, etc.), la propuesta además pretendía resolver en las principales áreas pecuarias del país (zona centro y centro-sur), específicamente las ciudades de Curicó, Talca, Chillán, Temuco y Valdivia, problemas de productores locales referidas al uso de leguminosas en la sustentabilidad y conceptualización de la integración de las variables y como afectan la obtención de un producto de calidad terminado.

La visión de un profesional externo en esta materia además contribuiría a complementar el análisis de fortalezas y debilidades del rubro, así como comparar el modelo australiano con el chileno, determinando las potencialidades existentes en el país.

Objetivos de la Propuesta

Generales:

- Transferir a productores, profesionales e investigadores vinculado al área pecuaria de la zona centro y centro-sur, tecnologías de nivel internacional para el desarrollo de sistemas sustentables productivos y la elaboración de productos pecuarios de calidad para la exportación.
- Mejorar la rentabilidad de los sistemas de producción animal a través del uso eficiente de recursos forrajeros, reducción de costos por fertilización, incremento en la productividad del suelo y optimización del manejo alimenticio animal, basado en sistema de producción limpia.
- Transferir nuevas formas de desarrollo de agricultura sustentable para reducir los costos; económicos, ecológicos y sociales; de los sistemas de producción animal de cada ecosistema visitado en la zona centro-sur del país.
- Transmitir a productores e investigadores chilenos, adaptaciones de los sistemas productivos pecuarios australianos, mejorando su economía aprovechando los mercados de exportación, demandando fundamentalmente la implementación de sistemas sustentables basados en leguminosas forrajeras como así el uso de modelos de simulación de sistemas pecuarios a pastoreo,

Específicos

- Realizar presentaciones técnicas para productores pecuarios y profesionales del área, en las ciudades de Valdivia, Temuco, Chillán, Curicó y Talca, en temas de desarrollo de sistemas forrajeros sustentables y su uso en la alimentación animal y de metabolismo ruminal para el mejoramiento de la alimentación, principal costo de la actividad pecuaria.
- Visitar predios productivos en las localidades de Valdivia (X Región), Temuco (IX Región), Chillán (VIII Región), Curicó y Talca (VII Región), y realizar en terreno reunión de trabajo con agricultores locales.
- Participar como expositor en el Simposio Internacional "Eficiencia biológica y socioeconómica de los sistemas pecuarios para nuevos mercados" organizado por la Universidad Católica del Maule y la Sociedad Chilena de Producción Animal.

2. Antecedentes Generales.
Describir aspectos de interés y cifras relevantes del país o región de origen del consultor, con énfasis en la situación agrícola y la situación del rubro que aborda la propuesta en particular (no más de 2 páginas).

El Dr Bellotti es profesor de praderas y de sistemas agropecuarios en la Universidad de Adelaida, Australia. Tiene veinticinco años de experiencia como investigador y conferenciante en ciencias pratenses. Su trabajo se centra en sistemas agrícolas dependientes de lluvias en el sur de Australia. Es consultor internacional, principalmente en China.

En el sur de Australia, las praderas crecen en rotación con cultivos bajo el sistema conocido como "ley farming". Típicas especies forrajeras cultivadas incluyen el trébol subterráneo, especies anuales del género *Medicago* y alfalfa. Las principales especies cultivadas son trigo, raps, cebada, arveja, haba, lupino, garbanzo y lenteja. Los agricultores combinan una rotación de cultivos y praderas de diversas maneras dependiendo de las condiciones de suelo y clima variando según los precios de productos de la cosecha y del ganado a prevalecer.

Los suelos en el sur de Australia son relativamente antiguos y generalmente infértiles. Grandes esfuerzos deben hacerse para mantener y mejorar la fertilidad de suelo. Contraste relevante a la situación con Chile, donde los suelos son relativamente jóvenes e intrínsecamente más fértiles. El clima en el sur de Australia es similar al clima de la zona centro centro-sur de Chile. En el sur de Australia, los cultivos se desarrollan con precipitaciones entre 250 y 600 milímetros de agua caída anual en promedio. La distribución mensual de las precipitaciones en el sur de Australia es similar a Chile central y centro-sur, ambas regiones experimentando inviernos húmedos y fríos, y veranos secos y calurosos. La región donde trabaja el consultor y el área visitada Chile son de latitud similar (32 a 37 ºS) lo que contribuye a la semejanza climática.

En los últimos 10 años, Australia ha tenido un cambio fundamental en el enfoque de su investigación agrícola. En Australia, así como en muchos otros países, el énfasis en la investigación agrícola se ha movido de, los intereses de incrementar la productividad, a solucionar problemas de sustentabilidad, incluyendo los beneficios económicos. Un ejemplo de esto, es la amenaza del incremento de la salinidad de suelos de secano. La salinidad de suelos de secano está incrementándose en Australia y amenaza la productividad de millones de hectáreas de suelo agrícola productivos. Adicionalmente existen problemas por el incremento en la salinización de agua subterránea provocado por el reemplazo de la vegetación perenne nativa existente por cultivos y pasturas anuales. La solución a este problema es introducir y establecer plantas perennes en los sistemas agrícolas para asimilar los patrones hídricos originales y al mismo desarrollar una actividad económicamente viable. Este es un desafío mayor para los agricultores, entidades de gobierno e investigadores.

En respuesta al complejo desafío de la salinidad de los suelos, el gobierno australiano con la ayuda de la empresa privada ha creado el Cooperative Centre for Plant Based Management of Dryland Salinity. Este centro desarrolla actividades a través de la mayoría de los estados de Australia y coordina la investigación de universidades, de organismos de investigación nacionales (CSIRO), y de organismos de investigación estatales. La industria y los agricultores también están involucrados en la definición y la conducción de la investigación y en la puesta en práctica de los resultados.

Durante la visita a Chile del consultor, se observaron amenazas a la sustentabilidad de los sistemas agrícolas locales, en términos biológicos y socioeconómicos (según lo descrito más adelante en este informe). Durante la breve estadía del consultor, no se pudo apreciar mayormente la respuesta del gobierno a estas amenazas, pero su primera impresión es la necesidad de una mayor coordinación de las actividades desarrolladas por este, para mejorar la eficacia de la investigación y reportar soluciones a los agricultores.

3. Itinerario desarrollado por el Consultor.
Presentación de acuerdo al siguiente cuadro:

Fecha	Ciudad y/o Localidad	Institución/Empresa	Actividad Programada	Actividad Realizada
14-Oct	Curicó	Universidad Católica del Maule	Reunión de trabajo con académicos del Dpto. de Ciencias Agrarias	Reunión de trabajo con académicos del Dpto. de Ciencias Agrarias. Visita predio Dpto. Cs. Agrarias.
15-Oct	Talca	Universidad Católica del Maule	Participación de Seminario productores regional "Sistemas de Producción Animal para la Región del Maule" en XXVIII Reunión Anual Sociedad Chilena de Producción Animal	Participación de Seminario productores en XXVIII Reunión Anual SOCHIPA. Vinculación con productores Región del Maule e Investigadores SOCHIPA.
16-Oct	Talca	Universidad Católica del Maule	Exposición Simposio en XXVIII Reunión Anual SOCHIPA, "Rol de los forrajes en sistemas sustentables agropecuarios"	Vinculación con investigadores SOCHIPA. Presentación trabajo en Simposio de SOCHIPA.
17-Oct	Talca	Universidad Católica del Maule	Participación XXVIII Reunión Anual SOCHIPA. Reunión de trabajo con directiva SOCHIPA e investigadores y extensionistas nacionales.	Intercambio personal de experiencias de extensión e investigación con profesionales chilenos.
18-Oct	Talca	Feria Los Agricultores. Empresa PF.	Gira de transferencia tecnológica a predios locales.	Visita predio lechero Productos Fernández. Visita predio cultivos y ganado Sr. Gastón Pozo.
20-Oct	Valdivia	Universidad Austral de Chile	Reunión técnica de trabajo con productores, investigadores, extensionistas y estudiantes. Gira de transferencia a predios locales.	Charla a agricultores y estudiantes localidad de Valdivia. Reunión con académicos UACH. Vista a predios localidad de Valdivia.
21-Oct	Temuco	INIA-CRI Carillanca	Reunión técnica de	Charla a estudiantes,

			trabajo con productores, investigadores, extensionistas y estudiantes. Gira de transferencia a predios locales.	profesionales del agro, agricultores e investigadores. Visita a predios agricultores localidad de Temuco.
22-Oct	Chillán	Universidad de Concepción Agrícola Pullamí Agricultor: Jaime Fuenzalida	Reunión de trabajo con académicos de la Fac. de Agronomía y Medicina Veterinaria de la Universidad de Concepción e investigadores de INIA CRI-Quilamapu. Gira de transferencia tecnológica a predios locales.	Reunión de trabajo en investigación aplicada. Charla a agricultores, profesionales, investigadores y estudiantes. Visita a predio Agrícola Pullamí.
23-Oct	Curicó	Universidad Católica del Maule. Lácteos Frölich. Engorda productor Guido Besomi.	Reunión técnica de trabajo con productores, de San Fernando y Curicó. Gira de transferencia tecnológica a predios locales.	Charla a agricultores, profesionales y estudiantes. Visita a predio lechero. Visita a predio engordero.
24-Oct	Santiago	Tránsito en retorno a Australia		
25-Oct	Santiago	Retorno a Australia		

Señalar las razones por las cuales algunas de las visitas o actividades programadas no se realizaron o se modificaron.

Las visitas y actividades programadas se realizaron sin inconvenientes.

4. Resultados Obtenidos.

Descripción detallada de las tecnologías conocidas (rubro, especie, tecnología, manejo, infraestructura, maquinaria, aspectos organizacionales, comerciales, etc.) y de la tendencia o perspectiva de dichas tecnologías en su lugar de origen. Explicar el grado de cumplimiento de los objetivos propuestos, de acuerdo a los resultados obtenidos. Incorporar en este punto fotografías relevantes que contribuyan a describir las tecnologías.

El desarrollo de la consultoría comprendió la evaluación y la recomendación para la implementación y desarrollo de sistemas pecuarios sustentables en la zona centro y centro-sur de Chile.

La consultoría realizada se centró en el ámbito principal de especialidad del consultor, la producción primaria o producción de forrajes. Además, se pudo evaluar los sistemas de producción animal de la región centro sur del país, formándose una idea acabada de la influencia del clima en la actividad agropecuaria nacional bajo el prisma holístico. El consultor realizó comparaciones de los sistemas nacionales con los sistemas australianos, generando una discusión en cada uno de las localidades visitadas, entregando su planteamiento y visión de los pasos a seguir para mejorar la calidad y productividad de los sistemas. La discusión se centró en los siguientes planteamientos:

- Rotación de cultivos con leguminosas forrajeras.

La visita del consultor permitió conocer nuevos avances en el uso de leguminosas forrajeras para el desarrollo sostenible de los sistemas agrícolas, que incluyen la rotación, usualmente dos o tres años de cultivos anuales y luego 5 a 7 años de praderas permanentes. El objetivo de ello se centra en la reducción del uso de fertilizantes, menor laboreo del suelo, control de erosión y mejor control de malezas. Adicionalmente, para el caso australiano, el uso de leguminosas previene la contaminación del suelo por exceso de salinidad.

- Sustentabilidad en los sistemas agropecuarios.

Se generó la discusión en el uso de los recursos naturales en los que se basa la agricultura, como son suelo y agua. En el uso del suelo se discute acerca de la capacidad de uso de los suelos utilizado en Chile, y de la técnica empleada en utilizarlos, discutiéndose acerca de los sistemas de producción orgánica versus los sistemas de producción tradicional, y su relevancia en las distintas agroecorregiones visitadas. Se plantean propuestas a aplicar en los diferentes ecosistemas.

- Aplicación de modelos de simulación en sistemas agrícolas.

Propuesta de creación de base de datos para la elaboración de modelos de simulación de sistemas agropecuarios acordes a cada agroecorregión.

- Enfrentamiento a variaciones de mercado. El caso australiano.

Traspaso de experiencia del consultor sobre el caso australiano frente al mercado mundial. Se debate sobre los tratados de libre comercio que Chile suscribe y cómo podría el sector agropecuario, principalmente el pecuario, enfrentar este nuevo escenario.

- Potencial productivo del secano.

Se realiza una propuesta para el secano de la VII región, producto de la discusión con agricultores de Curicó y Talca y académicos de la UCM.

El grado de cumplimiento de los objetivos planteados es satisfactorio, lográndose el objetivo 1, transmitiendo a productores, profesionales e investigadores, el uso de leguminosas, eficiencia del manejo del agua e importancia de modelos en la agricultura, como alternativas para la implementación de mejores prácticas agropecuarios.

En tanto el objetivo 2 y 3, aunque difícil de medir en el corto plazo por incluir una componente económica, la consultoría realizada proyectó a los productores, las ventajas económicas y ambientales del uso de leguminosas en las rotaciones, principalmente a través del ahorro de fertilizantes, mitigación de impacto ambiental y mejoramiento en el control natural de malezas.

Mediante la experiencia del consultor en el uso de modelos aplicados para el diseño e implementación de sistemas agropecuarios y extensión con agricultores australianos, se logró difundir la importancia del diseño y uso de prototipos computacionales o "sistemas expertos", para fortalecer la investigación, la administración y gestión predial, determinación de puntos críticos en el procesos productivo y predicción de potencial productivo, adaptándose a las distintas situaciones locales, para ser implementado en el futuro por los actores del medio pecuario nacional.

5. Aplicabilidad.
Explicar la situación actual del rubro en Chile (región), compararla con la tendencias y perspectivas de su lugar de origen y explicar la posible incorporación de las tecnologías capturadas, en el corto, mediano o largo plazo, los procesos de adaptación necesarios, las zonas potenciales y los apoyos tanto técnicos como financieros necesarios para hacer posible su incorporación en nuestro país (región).

Las potenciales áreas de aplicabilidad de la nueva tecnología se describen abajo. Además, se han incluido algunas directrices para el desarrollo, organización y manejo de la investigación. Estas han sido traducidas directamente del Informe del Consultor, que se anexa.

Potenciar el intercambio de germoplasma de cultivos y praderas.

Debido a las semejanzas de clima, ya existe un alto grado de intercambio de germoplasma de cultivos agrícola, al menos en una escala comercial. La mayoría de las leguminosas y gramíneas forrajeras introducidas en Chile son de origen Neocelandés (para aquellas zonas con altas precipitaciones) o Australiano (para zonas de bajas precipitaciones). La excepción a esta situación fue la alfalfa, donde la mayor parte del germoplasma fue importado desde los Estados Unidos de América.

Sin embargo, la mayoría de los cultivares australianos que se vieron en Chile son viejos y han sido reemplazado en Australia por cultivares más nuevos y superiores. Esto puede ser debido a que los cultivares australianos más viejos superan a los cultivares australianos más nuevos bajo condiciones chilenas, o las compañías de exportación de semilla australiana no han promovido los cultivares recientemente mejorados a los importadores chilenos.

Recomendación 1: Entregar a los científicos chilenos de praderas, financiamiento adecuado que les permita desarrollar un programa regional de evaluación de praderas. Este programa importaría germoplasma mejorado recientemente desde las fuentes locales relevantes y de las internacionales y evaluaría el material en una red de sitios cuidadosamente seleccionados y manejados en los principales suelos, clima, y sistemas agrícolas socioeconómicos representativos de Chile central y centro-sur. El apoyo financiero para esta iniciativa podría venir de una agrupación que involucre al gobierno, la empresa privada (como comerciantes de semillas), y agrupaciones de agricultores.

Aunque el consultor se ha centrado en el germoplasma de especies forrajeras, la misma estrategia se podría aplicar a los programas de mejora de cultivos en Chile. Probablemente ya existen algunos acuerdos formales para distribuir el mejor germoplasma disponible a los agricultores chilenos de manera oportuna, eficiente, y equitativa.

Actualmente en Australia ha existido una creciente inversión para la evaluación de una amplia gama de germoplasma de praderas para enfrentar la amenaza de la salinidad de los suelos. Algo de este material puede ser relevante para lugares específicos en Chile donde las praderas pueden tener un rol en la rehabilitación de ambientes degradados o en evitar que ocurra la degradación. La evaluación de este material debe ser considerada como una actividad separada de la evaluación para la mejora de praderas descrita en la Recomendación 1.

Recomendación 2: Formar un equipo multidisciplinario de ingenieros agrónomos especialistas en praderas, en suelo, en economía, y en ciencias sociales para investigar la necesidad de especies pratenses para la remediación ambiental en Chile. Dependiendo de la viabilidad de los resultado de los estudios, buscar financiamiento para establecer una red de evaluación regional y manejo de nuevos sistemas de praderas. Debe existir un especial cuidado el potencial riesgo de introducción de malezas al importar especies cultivadas no tradicionales.

Finalmente, debe ser reconocido que el intercambio de germoplasma será una interacción abierta de dos vías. La flora natural y naturalizada de Chile indudablemente contiene genotipos con potencial comercial en países extranjeros incluyendo Australia. Ejemplos históricos de esto incluyen los genotipos naturalizados de *Medicago polymorpha* en Chile y explotados comercialmente en Australia como cv. Santiago y cv. Serena. Durante la visita del consultor se pudo observar una pradera de serradella (*Ornithopus compressus*) que superaba cultivares australianos importados del trébol subterráneo. En el entorno de altas precipitaciones de la localidad de Valdivia, la pradera nativa de *Bromus valdivianos* superaba los rendimientos y la persistencia de especies importadas desde Nueva Zelanda. Estos pocos ejemplos ilustran el potencial de la flora nativa y naturalizada por lo que deben incluirse siempre en evaluaciones del germoplasma importado.

Recomendación 3: Investigación sistemáticamente para evaluar y explotar la flora nativa y naturalizada debería ser apoyada. Esta investigación se debe financiar por aquellos que se beneficien de las ganancias por aumentos potenciales de la productividad, y también por aquellos interesados en mantener y promover la biodiversidad.

Agronomía para sistemas agrícolas sostenibles.

Se analizará este punto basado en dos sistemas agrícolas socioeconómicamente contrastentes existentes Chile.

1. Predios comerciales extensos con alto nivel de inversión.

Los predios visitados en Chile se encuentran en esta categoría. Son caracterizados por una superficie relativamente grande (100 a más de 1.000 has), alta inversión en trabajo, maquinaria, riego, fertilizantes, labranza, y son generalmente altamente productivos.

Desde una perspectiva australiana el uso del agua de riego parece ser desperdiciada e ineficiente. Chile se bendice afortunadamente con abundantes recursos hídricos para el riego. En la mayoría de los años hay una fuente adecuada de agua, aunque escasez ha ocurrido en años recientes. En Australia, el agua de riego es limitada y gran importancia se le ha dado en mejorar su eficiencia de uso, reduciendo los impactos negativos del riego sobre el incremento en la salinidad del suelo y del agua subterránea, percolación de nitratos, y la contaminación de fuentes de agua subterránea. En Chile parece existir sólo un leve conocimiento del potencial de degradación ambiental resultando de prácticas ineficaces de riego.

Recomendación 4: Financiar, diseñar e implementar estudios de caso detallados de balance hídrico en predios representativos y claves para el desarrollo de la agricultura. El objetivo de estos estudios de caso sería analizar el balance de agua en sus componentes fundamentales (precipitación, riego, evaporación, transpiración, escurrimiento superficial, drenaje, retención de agua en el suelo) para una gama de situaciones representativas. Tópicos relacionados tales como la percolación de nitratos y dinámicas de sales se podrían incluir también en esta investigación. Esta investigación es compleja y costosa de conducir. Debe existir un apoyo económico realista, liderazgo, participación de equipos multidisciplinarios, y compromiso de los agricultores.

Otra característica de estos sistemas de agricultura local, era la alta frecuencia e intensidad de laboreo del suelo. Suelo en barbecho era común y los instrumentos de labranza incluyeron los arados de disco y labores de suelo profundizantes. En Australia y en todo el mundo existe una tendencia a la mínima y cero-labranza. Los beneficios de la mínima labranza, a veces llamada laboreo de conservación, incluyen la reducción en la erosión del suelo, mejoramiento de la fertilidad del suelo, mantención o incremento en los rendimientos en la producción de granos, y reducción de los costos directos. Sin embargo, estas ventajas puede que no reflejarse en las características específicas de la agricultura chilena.

Recomendación 5: Revisar la investigación existente que compare sistemas de mínima y cero-labranza con los sistemas tradicionales de establecimiento de cultivos. Según esta revisión, recomendar un programa de investigación dirigido a demostrar los beneficios del laboreo de conservación a grupos de agricultores locales. El equipo de investigadores debe incluir ingenieros agrónomos, edafólogos, economistas y a agricultores.

Otra característica de estos sistemas de alta-inversión, alta-produccioón era que no eran siempre sistemas de alta-rentabilidad. Un ejemplo era el sistema de lechería en confinamiento que estaba en proceso de conversión a un sistema de engorda de carne para exportación. Es importante que toda la investigación agronómica incluya un análisis económico del sistema existente y del propuesto.

2. Predios pequeños de subsistencia, de baja-inversión.
Estas granjas se caracterizan como pequeñas (5-20 has), de baja-inversión, baja productividad, y de subsistencia. Están situadas generalmente en las tierras marginales no seleccionadas por los primeros colonos. Una alta proporción de estos granjeros son mapuches. Desgraciadamente, el consultor no visitó alguno de estos granjeros, a pesar del hecho que en algunas áreas, como Chillan, estas granjas ocupaban una extensión similar a los predios más grandes y más ricas.

A pesar de no visitar estas granjas o reunirse con estos granjeros, el consultor tuvo la oportunidad de discutir la situación con varios investigadores y extensionistas que tenían cierta experiencia en estos sistemas. Está claro que el nivel de la productividad actual en muchos de estos predios es extremadamente bajo. Está también claro que el potencial de aumentar la productividad es bastante grande con aumentos sustanciales en el manejo de la pradera y de los animales según lo divulgado en diversos estudios. Estos incrementos se han logrado aplicando conocimientos existentes en el desarrollo de praderas y de la producción animal. El potencial para un importante aumento en la productividad por lo tanto existe, para una gran proporción de agricultores y esto es abre una perspectiva interesante con la promesa de retornos excelentes en los fondos de investigación invertidos en esta área. Sin embargo, la situación socioeconómica es compleja y muchas barreras para la adopción de nuevas tecnologías, algunas bien conocidas y otras no entendidas, existen.

> *Recomendación 6:* Formar un equipo multidisciplinario, conducido por científicos de las ciencias sociales, que incluya a ingenieros agrónomos, zootecnistas, edafólogos, y economistas, para desarrollar una propuesta de negocio de inversión en mejorar la productividad, sostenibilidad, y la rentabilidad de pequeños agricultores. Esta propuesta de negocio debe incluir ofertas de inversión en regiones y productos específicos. La inversión propuesta se debe apoyar en investigación relevante y la demostración efectiva de sistemas de producción mejorados. La relevancia de la propuesta debe ser determinada por un amplio grupo de actores del medio, incluyendo los agricultores que se espera implementen la propuesta. Los criterios para la inversión deben incluir retornos económicos pero deben también considerar las preocupaciones ambientales, equidad social, y mantenimiento de la cultura tradicional.

Desprendiéndose de esta amplia iniciativa de gran envergadura, surgirían nuevas empresas o sistemas agrícolas específicos que requerirán demostraciones en zonas determinadas bajo la administración de comunidades locales. Lo siguiente es sólo un ejemplo de esto.

La producción animal actual es limitada debido a la baja productividad de praderas no mejorados y el deficiente manejo animal. La investigación ha demostrado que el uso de fertilizantes fosforados y de la introducción de semillas de leguminosas inoculadas bien adaptadas, aumenta la producción y la calidad de la alimentación ofrecida para el pastoreo. El incremento en la producción de la pradera puede aumentar la capacidad de carga y permite la conservación del forraje para la alimentación durante los meses secos del verano. El resultado final es la venta creciente de productos animales y mejoramiento en la rentabilidad del negocio. ¿Por qué este sistema no es adoptado más extensamente?

La respuesta a esta pregunta requiere experticia socioeconómica. La manera de enfrentar la situación es trabajar de cerca con los agricultores que se espera implementen el nuevo sistema propuesto. Sus preocupaciones y apremios deben ser considerados al adaptar el nuevo sistema a su situación particular.

Desarrollar la capacidad para la simulación de sistemas agrícolas.

En Australia las herramientas de simulación de sistemas agrícolas han logrado una extensa aceptación entre científicos, extensionistas, agricultores, y legisladores. El consultor presenta su experiencia en los sistemas APSIM y GrassGro.

APSIM (Agricultural Production Systems Simulator o Simulador de Sistemas de Producción Agrícola) fue desarrollado en Australia para ayudar a entender y administrar sistemas agrícolas. El programa proyecta la producción de la cosecha y de la pradera, la dinámica del agua y del nitrógeno en el suelo, y la rentabilidad. El programa requiere entradas de parámetros climáticos diarios, de una gama de parámetros del suelo que describen la disponibilidad del agua y del nitrógeno del suelo, y de parámetros detallados que describen el crecimiento y el desarrollo de los cultivos y pasturas de interés. El programa se utiliza en la investigación para el desarrollo de variedades nuevas de cultivos y praderas, manejo de fertilizantes, programación de riego, estudios de rotación de cultivos y praderas, y análisis de riesgos climáticos.

GrassGro también se ha desarrollado en Australia como apoyo al manejo de praderas. La producción de praderas y la producción animal, como la rentabilidad del negocio, es predicha mediante programa de datos diarios de clima, parámetros del suelo, y parámetros de la pradera y del ganado, describiendo la pradera en particular y los animales en cuestión. GrassGro se aplica bien a la eficiencia del uso de praderas y para optimizar la alimentación suplementaria del ganado a pastoreo. GrassGro también predice bien el crecimiento animal en engordas y puede ser utilizado para una integración óptima de la pradera y fuentes de alimentos para producir un animal terminado en una fecha predeterminada.

Estos modelos de simulación en Australia y a nivel internacional han desarrollado un importante conocimiento científico y son el resultado de una gran inversión de los fondos disponibles para la investigación en Australia. Existe la oportunidad para una organización de investigación y/o de educación en Chile para capitalizar esta inversión adaptando estos modelos a las necesidades locales. Tal decisión requeriría un compromiso a largo plazo por la organización chilena para entrenar a un grupo de científicos en el uso de los modelos y en desarrollar y aplicar los modelos a situaciones locales. La experiencia en Australia es que el progreso es mayor cuando el uso de modelos de simulación y la investigación se combinan en un equipo multidisciplinario. La selección de los científicos para conformar el equipo de modelación incluiría idealmente ingenieros agrónomos, zootecnistas, edafólogos y sociólogos. Aptitudes personales para analizar sistemas y conceptualizar los procesos matemáticos implicados son también deseables.

> *Recomendación 7:* Designar un equipo de evaluación para determinar si la inversión en desarrollar modelos de simulación fuese deseable desde una perspectiva chilena. Este equipo debe ser apoyado para visitar Australia para tener reuniones con los desarrolladores claves de los sistemas de simulación, ubicados en Toowoomba (APSIM) y Canberra (GrassGro). Existe una interesante oportunidad de coincidir esta visita con el 4to Congreso Científico Internacional de Cultivos que se sostendrá en Brisbane en septiembre de 2004, donde ejemplos de investigación en modelos de simulación se expondrán.

Una complementación a la recomendación recién descrita sería que el gobierno chileno financie un determinado número de becarios de postgrado y así apoye a científicos a estudiar en las universidades australianas para formar expertos usuarios de APSIM y/o de GrassGro. Estos estudios de postgrado podrían aprovechar la modalidad de "split program" donde el estudiante divide su tiempo entre Chile y Australia. Bajo esta modalidad, los doctorando chilenos pueden aplicar el nuevo conocimiento en la simulación de modelos locales como parte de su programa de investigación de PhD.

Recomendación 8: Financiar mediante fondos gubernamentales, varias becas de postgrado y así permitir a científicos chilenos matricularse en las universidades australianas y contribuir al desarrollo de capacidades humana en la simulación de sistemas agrícolas.

Desarrollar una mayor participación de los agricultores locales en la investigación.

En los últimos años, una importante tendencia en la investigación y administración agrícola australiana, ha sido la incorporación de los productores en el diseño y la puesta en práctica de la investigación. En el pasado la investigación fue conducida en gran parte sin tomar en cuenta a los productores y los resultados eran transferidos a la comunidad agrícola, a veces con bajos niveles de adopción de la tecnología desarrollada. En el presente, los productores y administradores agrícolas están involucrados formalmente en el planeamiento de la investigación, la puesta en práctica, y ejecución de la investigación, usualmente desarrollada en los mismos predios de los agricultores. La adopción de la tecnología generada bajo esta modalidad es a menudo alta dado que los agricultores "son dueños" de la investigación y están seguros que la investigación es relevante para su situación específica.

En Australia, un número importante de programas coordinados a nivel nacional han tenido éxito considerable en lograr altos niveles de adopción de prácticas agrícolas mejoradas. Ejemplos notables incluyen:

- Cuidado del suelo (Landcare), programa nacional para cultivar de una manera más sostenible.
- Topcrop, programa dirigido a los agricultores para adoptar mejores prácticas productivas y sostenibles en los cultivos de grano.
- Sistemas de Pastoreo Sustentable (SGS), programa dirigido a mejorar la adopción de sistemas de pastoreo más productivos y sostenibles.

Todos estos programas exitosos han incluido una importante participación de agricultores, en la identificación de las necesidades de investigación, la conducción y demostración de la investigación en terreno, y promoción de resultados a otros agricultores. En Australia la posición de los agricultores es consolidada más aún a través de sus contribuciones a través de recaudaciones para las Corporaciones de Investigación y Desarrollo de la Industria Rural que financien mucha de la investigación agrícola en Australia.

Recomendación 9: Apoyar a través del gobierno de Chile a grupos de científicos, de extensionistas, y de agricultores para visitar Australia a ver ahí el efecto de la inclusión de los agricultores en la investigación agrícola de Australia. Tal visita requeriría una duración de 2-4 semanas para recorrer varios estados (New South Wales, Victoria, South Australia) y permitir que los visitantes vean los programas de Landcare, Topcrop y de SGS en ejecución.

La recomendación antedicha podría tener implicaciones de gran envergadura para el desarrollo de la investigación agrícola en Chile. En particular, esta recomendación apoya en forma global las recomendaciones más específicas 1 a la 8.

Administración y gestión de la investigación.

Una característica de los fondos de investigación en Australia es la existencia de las Corporaciones de Investigación y Desarrollo de la Industria Rural. Estas corporaciones recaudan aportes de los agricultores basados en la producción predial. Las recaudaciones logradas son igualadas entonces por el gobierno australiano sobre la base de un dólar por dólar recaudado. Existen corporaciones de Investigación y Desarrollo (I+D) para la industria de granos (GRDC, Grains Research y Development Corporation), industria de la carne (MLA, Meat and Livestock Australia), industria de la lana (AWI, Australia Wool Innovation), y los recursos de suelo y agua (LWA, Land and Water Australia), entre otros.

Cada corporación es manejada por una directiva que incluye a los agricultores, a la industria, y representantes de los científicos. Los fondos se distribuyen anualmente sobre una base competitiva basada en las prioridades desarrolladas por la industria. Los fondos distribuidos por las corporaciones tienen una fuerte influencia sobre las directrices de otros fondos de financiamiento del gobierno.

Otra característica de la investigación en Australia es el programa de Centros de Investigación Cooperativo del gobierno de Australia (CRC). El programa de CRC apunta a reunir investigadores de las universidades, de las organizaciones de investigación nacionales y regionales, y de las empresas a focalizarse en un tópico específico. Ejemplos de distintos CRC incluyen el CRC para el control de la salinidad de suelos en secano, el CRC para el control de malezas, el CRC para el desarrollo genético vegetal, y el propuesto CRC para la variabilidad climática y riesgo de sequía.

Los CRC potencian la colaboración conjunta mediante el financiamiento y reducción en la duplicación y la competencia por los fondos. Todos los CRC tienen los programas científicos básicos y aplicados como programas educativos y de extensión a la comunidad. El programa de los CRC no está exento de críticas pero sin duda han demostrado éxitos relevantes.

> *Recomendación 10:* Financiar a un grupo de científicos de vasta trayectoria en la asignación de fondos para la investigación, para visitar Australia y evaluar la organización de la distribución y administración de los fondos para la investigación agrícola. La visita en particular al debe incluir a las Corporaciones de Investigación y Desarrollo de la Industria Rural y los Rural Industry Research & Development Corporations y el programa de los Centros de Investigación Cooperativo. Ambos programas se administran fuera de Canberra y la visita debería incluir visita a centros regionales para considerar cómo los programas se transfieren a agricultores.

6. Contactos Establecidos.
Presentación de acuerdo al siguiente cuadro:

Institución/ Empresa	Persona de Contacto	Cargo/ Actividad	Fono/Fax	Dirección	E-mail
Universidad de Adelaida	Dr. William Bellotti	Académico School of Agriculture and Wine	+61-8-8303-7728 +61-8-8303-7979	Roseworthy SA 5371	william.bellotti@adelaide.edu.au

7. Detección de nuevas oportunidades y aspectos que quedan por abordar.
Señalar aquellas iniciativas detectadas durante la consultoría, que significan un aporte para el rubro en el marco de los objetivos de la propuesta, como por ejemplo la posibilidad de realizar nuevas consultorías, giras o cursos, participar en ferias y establecer posibles contactos o convenios. Indicar además, en función de los resultados obtenidos, los aspectos y vacíos tecnológicos que aún quedan por abordar para la modernización del rubro.

A través de los vínculos generados entre el Dr. Bellotti con productores, académicos y entidades privadas nacionales, surgieron una serie de iniciativas para desarrollar al corto y mediano-largo plazo.

En lo inmediato se presentan las siguientes oportunidades de actividades a desarrollar:

1. Convenio marco entre la Universidad Católica del Maule y la Universidad de Adelaida para la colaboración conjunta en el desarrollo de proyectos de investigación y extensión relacionados con tópicos de Diseño y Manejo de Sistemas Agropecuarios Sustentables.

2. Desarrollo de investigación en aplicación de modelos australianos (APSIM y GrassGro) en Chile, como apoyo para la determinación del potencial productivo pratense y pecuario, administración predial y diseño de sistemas agropecuarios.

3. Investigación y extensión en evaluación de especies forrajeras y fortalecimiento de la actividad pecuaria en el sector de secano. Especial interés se generó a este respecto por la empresa nacional de semillas ANASAC de fortalecer acciones conjuntas con el Dr. Bellotti, para la evaluación de nuevos cultivares y especies forrajeras.

Considerando la naturaleza de las actividades y los mayores recursos involucrados para su realización, se presentan las siguientes iniciativas para poder desarrollar en el mediano-largo plazo:

1. Agrupar productores para realizar Gira de Transferencia Tecnológica a Australia y visitar distintas agrupaciones campesinas en el sur de Australia, observando vínculos estratégicos entre productores y universidades, programas de extensión, y capacidad de ajuste de productores a variaciones en los mercados de exportación.

Evaluar *in situ* nuevos manejos, especies forrajeras y conocimientos actualizados en la implementación de sistemas productivos para, la reducción de uso de fertilizantes, el control de malezas, la inocuidad de alimentos producidos, la implementación de trazabilidad y el mejoramiento en la calidad de los productos elaborados. A propuesta del Dr. Bellotti, se recomienda ejecutar esta actividad coincidiendo la visita a Australia con el Congreso Internacional de Cultivos a realizarse en septiembre en ese país y participar de ferias de promoción de productos nacionales.

2. Estudios de doctorado en la Universidad de Adelaida de investigadores chilenos en el área de ecosistemas pratenses y aplicación de modelos en agricultura, conduciendo investigación aplicable a la realidad chilena, a través de programas de postgrado de tiempo dividido (parte del tiempo en Australia y parte del tiempo en Chile), desarrollando ensayos en localidad chilenas.

3. Publicación de boletines divulgativos y escritos científicos en revistas de investigación y de extensión, con artículos relacionados al desarrollo de sistemas sustentables y generación de productos pecuarios de calidad para la exportación.

Considerando la idiosincrasia del agricultor chileno y las dificultades presentes en la generación de agrupaciones campesinas, inevitablemente las proyecciones de resultados y transferencia de nuevas tecnologías a nivel de productor exigen de programas extendidos en el tiempo. Los agricultores participantes de la consultoría, se vieron con mucho entusiasmo, y recogieron interesadamente los instrumentos y conocimientos entregados por le Dr. Bellotti, valorando el esfuerzo del consultor y de la entidad responsable y los proponente del proyecto, por fortalecer el rubro pecuario de exportación. Gran expectación de han hecho los productores de ver mejoras en sus ingresos mediante la exportación de productos, sin embargo, pocos identifican la importancia de las exigencia mundiales impuestas directa o indirectamente a los sistemas productivos, de desarrollarse en forma sustentable y planificada, exigiendo calidad sobre cantidad. El presente proyecto adicionalmente contribuyó a transmitir a los productores los compromisos que deben asumir para alcanzar los mercados de exportación, sin embargo, queda de manifiesto la necesidad de realizar mayores esfuerzos en este punto, enfrentando otras debilidades además de las cubiertas por esta consultoría, tales como bienestar animal, desarrollo socioeconómico, alimentación animal y gestión empresarial agrícola.

8. Resultados adicionales.
Capacidades adquiridas por el grupo o entidad responsable, como por ejemplo, formación de una organización, incorporación (compra) de alguna maquinaria, desarrollo de un proyecto, firma de un convenio, etc.

La gira realizada y los vínculos logrados con el Dr. Bellotti permiten además informar de los siguientes resultados adicionales obtenidos:

1. *Apoyo a productores:* El interés mostrado por parte de los productores en el tema en cuestión así como la accesibilidad del consultor para con los agricultores, permitieron generar un interesante vínculo consultor-agricultor. Productores señalaron la importancia de esta consultoría, la necesidad de repetirla y conocer en más detalle la forma de implementar nuevas formas de desarrollar agricultora, el uso de modelos y la intencionalidad de fortalecer la investigación aplicada a sus necesidades. Por su parte, el consultor acogió a los agricultores en cuanto a extender su consultoría y facilitarles giras tecnológicas de productores a su país a conocer los sistemas productivos australianos y fortalecer así los conocimientos adquiridos.

2. *Vínculo asociativo académicos/investigadores con Universidad de Adelaida:* Aunque sin firmarse convenio formal, la visita del Dr. Bellotti permitió establecer las bases de un nuevo contacto entre académicos e investigadores chilenos con la Universidad de Adelaida, permitiéndose fortalecer el desarrollo de la investigación y extensión a través de la comunicación, compartir resultados y experiencias, y estructurar soluciones a problemas determinados. Este vínculo ya ha puesto en marcha la aplicación de modelos australianos para la determinación y proyección del potencial productivo de distintas localidades chilenas, mediante la aplicabilidad de APSIM y GrassGro con datos de Chile, canalizado a través de los distintos proponentes locales. Datos climáticos de Talca, Chillán, Temuco y Valdivia ya han sido facilitados al Dr. Bellotti para ser ingresados a los programas y proyectar la producción pecuaria de esas localidades. Eventuales publicaciones científicas podrán generarse de esta información.

3. *Desarrollo de proyecto en sistemas productivos agrícolas sustentables:* La Escuela de Agonomía de la Universidad Católica del Maule, tiene entre sus líneas académicas fundamentales, el desarrollo de la agricultura sustentable, investigando especialmente alternativas e implementación de sistemas productivos, uso de modelos en la agronomía, rotación de cultivos, reducción del impacto ambiental de la actividad agropecuaria y desarrollo rural. La visita del Dr. Bellotti complementa el proyecto de esta unidad, en cuanto se logró un estrecho vínculo académico, enfrentando cuestionamientos de, ¿qué, para qué, y cómo desarrollar investigación y extensión en este ámbito? Adicionalmente surge la inquietud científica conjunta de desarrollar proyectos de investigación especialmente en la rotación de cultivos y praderas, y el desarrollo económico y social de la zona de secano, aprovechando las similitudes existentes en el sur de Australia y la Región del Maule.

4. *Estudios de doctorado en Australia:* El Dr. Bellotti mediante su visita ha abierto la Universidad de Adelaida para eventuales estudios de postgrado de chilenos,

especialmente en el área de diseño y manejo de sistemas agropecuarios sustentables y aplicación de modelos en la agricultura para investigar y desarrollar el potencial productivo local, áreas que se proyectan como necesarias en el país y falta de especialistas en esos temas.

9. Material Recopilado.

Junto con el informe técnico se debe entregar un set de todo el material recopilado durante la consultoría (escrito y audiovisual) ordenado de acuerdo al cuadro que se presenta a continuación (deben señalarse aquí las fotografías incorporadas en el punto 4):

Tipo de Material	Nº Correlativo (si es necesario)	Caracterización (título)
Artículo	-	The role of pasture legumes in sustaining productive and efficient cropping systems. [El rol de las leguminosas forrajeras en la mantención productiva y eficiente de los sistemas de cultivos]
Presentación Power Point	-	Archivo: Chile.ppt The role of pasture legumes in sustaining productive and efficient cropping systems. [El rol de las leguminosas forrajeras en la mantención productiva y eficiente de los sistemas de cultivos]
Presentación Power Point	-	Archivo: Chile_south.ppt Presentación a productores chilenos Sostenibilidad de los sistemas agrícolas
Documento Adobe Acrobat	-	GrassGro publications
Documento Adobe Acrobat	-	GrassGro Quality Assurance Simulations

10. Aspectos Administrativos.

10.1. Organización antes de la llegada del consultor

a. Conformación del grupo proponente

____ muy dificultosa __X__ sin problemas ____ algunas dificultades

b. Apoyo de la Entidad Responsable

____ bueno ____ regular ____ malo

Para evitar la autoreferencia, el coordinador de la propuesta prefiere omitir responder esta pregunta.

c. Trámites de viaje del consultor (visa, pasajes, otros)

__X__ bueno ____ regular ____ malo

d. Recomendaciones (señalar aquellas recomendaciones que puedan aportar a mejorar los aspectos administrativos antes indicados)

La buena comunicación entre la Agencia de Viajes responsable de la adquisición del pasaje, del consultor, el coordinador de la propuesta y del supervisor FIA, facilitada por el sistema de correos electrónicos, permitió resolver a tiempo algunos inconveniente presentados con el envío del pasaje al consultor a Australia. Se sugiere entonces simplemente asegurar el buen funcionamiento de los servicios de comunicación electrónicos, por parte de cada uno de los involucrados en la administración del proyecto.

10.2. Organización durante la consultoría (indicar con cruces)

Ítem	Bueno	Regular	Malo
Recepción del consultor en el país o región	X		
Transporte aeropuerto/hotel y viceversa	X		
Reserva en hoteles	X		
Cumplimiento del programa y horarios	X		
Atención en lugares visitados	X		
Intérpretes	No se aplica. Los proponentes hicieron de intérpretes		

En caso de existir un ítem Malo o Regular, señalar los problemas enfrentados durante el desarrollo de la consultoría gira, la forma como fueron abordados y las sugerencias que puedan aportar a mejorar los aspectos organizacionales de otras consultorías.

11. Evaluación del consultor.
La contraparte nacional (grupo proponente) debe realizar una evaluación del consultor en términos de si constituyó un real aporte al conocimiento del rubro o tema de la propuesta en Chile (región). Evaluar su calidad profesional y técnica y su capacidad de interacción con los agentes del sector.

El momento que vive la ganadería nacional hace relevante cuestionarse sobre aspectos técnicos de producción, como es el manejo de praderas y forrajes, base de la alimentación de rumiantes en el mundo, además de analizar la producción animal desde el punto de vista económico y ambiental. El Dr Belloti, fue un muy bueno integrador de estos 3 aspectos, por su formación en sistemas de pastoreo, y su visión agro ecológica de estos. El aporte principal, es de dar una mirada objetiva de cómo estamos haciendo ganadería en Chile, como estamos produciendo el forraje, el efecto de las tecnologías aplicadas en el ecosistema y el margen económico que el negocio entrega al productor. Esto concuerda con los objetivos que como institución proponente se planteó, y se logró.

El DR Belloti, es un profesional joven y visionario, con una formación sólida en ecología de praderas, sistemas de producción animal y agricultura sustentable, con una basta trayectoria como investigador y docente. Demuestra un dominio de conocimientos teóricos y prácticos, lo que se puede ver fácilmente en terreno. Su base científica le permite opinar en diversos aspectos del quehacer agropecuario, lo que quedo en evidencia durante la Reunión de SOCHIPA, donde se realizó un fuerte debate donde participaron profesionales destacados en el ámbito nacional e internacional. Además, tuvo la oportunidad durante su visita de discutir sobre la tesis doctoral de un estudiante de la universidad Austral de Chile, proponiendo algunas evaluaciones que no habían sido consideradas por los patrocinantes nacionales.

En los encuentros con productores, tuvo la oportunidad de entregar algunas indicaciones practicas en el manejo del agua, de agroquímicos mediante ejemplos prácticos. Esto implica, su capacidad de entregar los conocimientos de tal forma que los agricultores puedan concretarlos, a pesar de que éstos muchas veces no tienen formación profesional ni técnica.

12. Informe del Consultor.
Anexar un informe realizado por el consultor, con las apreciaciones del rubro en Chile (región), sus perspectivas y recomendaciones concretas para la modernización o mejoramiento de éste en el país y/o a nivel local.

Se incluye en anexo adjunto, Informe del Consultor (en inglés), con antecedentes generales de su visita, actividades desarrolladas a nivel predial, comentarios referidos a sistemas agrícolas de pequeños productores, recomendaciones de posibles acciones a seguir, itinerario, agradecimientos y referencias bibliográficas. Dada la relevancia de las sugerencias planteadas, se han traducido las Recomendaciones realizadas por el consultor, incluyéndolas en el capítulo N° 5, "aplicabilidad" de este informe.

El coordinador de la propuesta queda gustoso de traducir el Informe del Consultor en su totalidad, en caso que así se estime conveniente.

13. Conclusiones Finales.

De la consultoría desarrollado por el Dr. William Bellotti, de la Universidad de Adelaida, Australia, entre los días 14 y 25 de octubre de 2003 se concluye lo siguiente:

1) Las leguminosas forrajeras cumplen un rol fundamental en el desarrollo de sistemas agrícolas sustentable, a través de la optimización del uso del suelo en rotación con otros cultivos, reducción del uso de fertilizantes, control de erosión hídrica en sistemas intensivos y mejoramiento en el control de malezas.

2) Es fundamental contar con información de variables productivas prediales y regionales, para el desarrollo de sistemas expertos en el país, y facilitar la transferencia tecnológica por este medio.

3) Las condiciones climáticas del sur de Australia con el secano de la zona centro de Chile, podría existir en esta zona un alto potencial productivo, no siendo difícil emular la experiencia desarrollada en Australia en producción animal. Es fundamental para ello complementar trabajos ya desarrollados en el país, relacionados con la evaluación de producción y calidad nutritiva de especies forrajeras, estudios de tecnologías productivas, desarrollo rural y manejo animal.

4) Los avances en el desarrollo pecuario nacional dependen del trabajo asociado de investigadores y productores, promovidos por una política agropecuaria nacional tal, que permita el incentivo y acceso a nuevos mercados como ha surgido mediante los tratados de libre comercio recientemente firmados. Referente de esto es el caso Australiano, en que dicha asociación ha permitido trazar las principales líneas de investigación de el rubro agropecuario de ese país y ha logrado extender en forma eficaz los resultados obetenidos.

5) La obtención de productos de calidad está asociada al sistema de producción que se implemente. Bajo los estándares internacionales de calidad de producción, se exigen incluir prácticas que consideran bienestar animal, inocuidad de los alimentos, trazabilidad, equidad social, conservación de los recursos naturales y rentabilidad económica.

Fecha: 28 de enero de 2004

Nombre y Firma coordinador de la ejecución: Daniel Andrés Troncoso Boys

FUNDACION PARA LA INNOVACION AGRARIA
UNIVERSIDAD CATOLICA DEL MAULE - ESCUELA DE AGRONOMIA

VISITA CONSULTOR ESPECIALIZADO

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18 de Octubre de 2003

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día Lunes 20 de Octubre
Lugar: Universidad Austral - Valdivia

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4.- Mauricio E. Riffo P.	Estudiante Agronomía
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8.- Cristian Muñoz Bernal	ESTUDIANTE AGRONOMÍA.
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13. Luis Gómez Pulgar	Estudiante.
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45	Jessica Carrión S.	Agricultor
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47	BRUNO TWELE.	AGRICULTOR.

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Participantes de Charla en Chillán, 22 de octubre de 2003

Consultor Internacional
Dr. William Douglas Bellotti
Universidad de Adelaida, Australia

Implementación de sistemas productivos pecuarios sustentables en la zona centro-sur de Chile.

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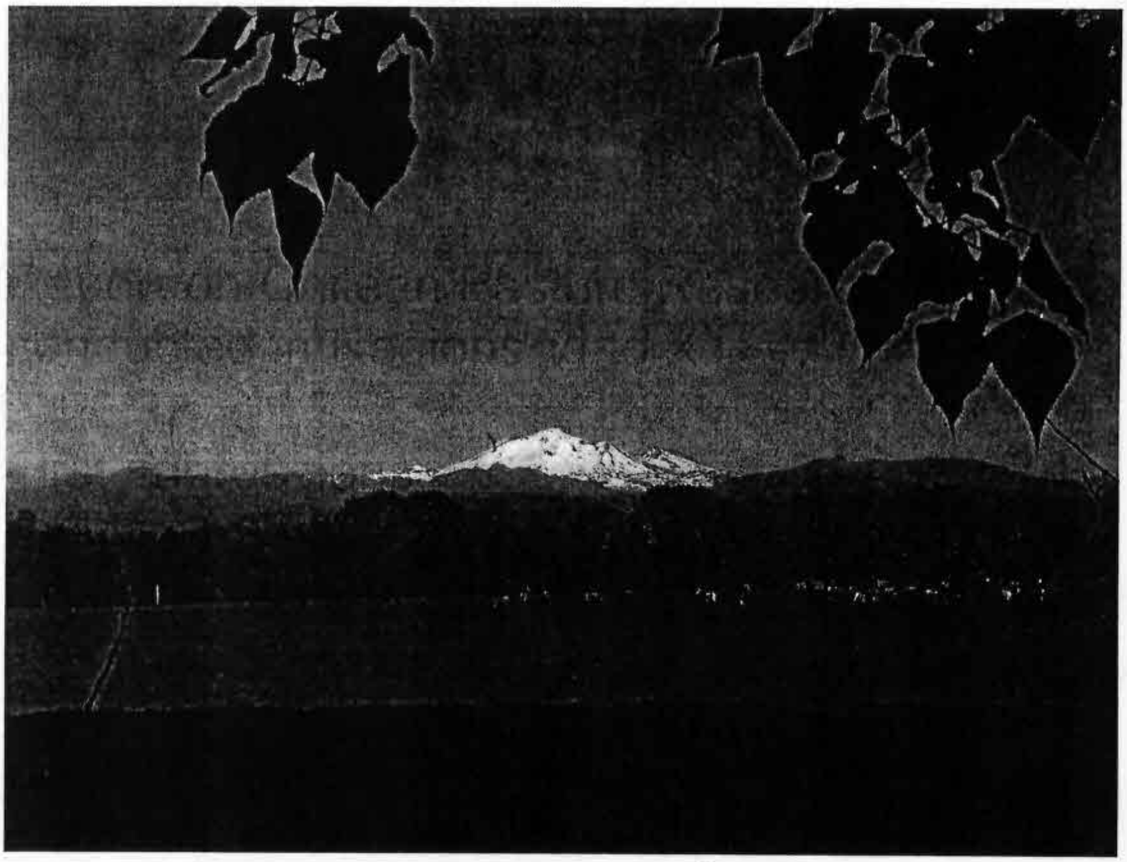
ANEXOS

Report on Chilean Pasture Research conducted in Regions VI to X.

First impressions.

Curicó – Talca – Chillán – Temuco – Valdivia



Dr William Bellotti
University of Adelaide, Australia

October 2003

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Cover photo
Cattle on irrigated white clover ryegrass pasture, 30 km east of Chillán. Volcano in the background.

Introduction

This report details a brief visit to Regions VI to X of Chile (see Map) to inspect pasture research and pasture production issues on farms in the regions. The visit was very brief (see itinerary) and so this report should be viewed as a "first impression" of the issues and possible research priorities.

My visit to inspect pasture research in these regions was made possible by an invitation to present a review paper to the XXVIII Annual Meeting of Chilean Society of Animal Production. The title of my paper was "The role of pasture legumes in sustaining productive and efficient cropping systems". The Chilean Ministry of Agriculture provided financial support to attend the conference and the associated visit to research stations and farms and I am grateful for this support.

I was impressed by the quality of the pasture research conducted by my Chilean counterparts. They gave freely of their time and knowledge and welcomed me with typical Chilean hospitality. They are the experts on pasture research in Chile and naturally I defer to them in matters of local knowledge and expertise. Nevertheless, it is sometimes useful to gain an outsider's perspective and it is in the spirit of constructive criticism that I offer the observations contained in this report.

I have deliberately, and somewhat provocatively, given the subtitle "First Impressions" to this report. There are two reasons for this. Firstly, I want to acknowledge that I am very inexperienced in all things Chilean, including Chilean pasture research. Secondly, I hope there will be opportunities for "Second Impressions" and beyond. Later in this report I detail opportunities for research collaboration between Chilean and Australian agricultural scientists. Also, there are opportunities for postgraduate research for Chilean students at the University of Adelaide. Future collaboration will require funding and I would like to signal from the outset that I would welcome an ongoing dialogue with the Chilean government to pursue these opportunities.

Map 1. Travel undertaken is indicated in freehand. Note that my home town of Adelaide is located at 36° south, the same latitude as the Temuco-Chillan region.

Detailed field visit notes

14 October Curico

Here I was given a brief tour of the 15 ha campus of the Universidad Catolica Del Maule by Mr Daniel Troncoso and Ms Pamela Williams. Issues raised during the tour included nitrate pollution of groundwater resulting from high nitrogen fertiliser application. Observed flood irrigation of pastures which seems to be the normal practice in Chile but is seen as inefficient in Australia. Irrigation water is generally regarded as plentiful in Chile but there are shortages in some years indicating the opportunity for improving water use efficiency.

I met with local academic staff and we discussed the diversity of local agricultural systems. In the immediate vicinity of the campus, high value horticultural crops are dominating land use at the expense of irrigated crops and pastures. We briefly discussed land use on the 15 ha campus farm. The plan at the time was to devote 10 ha to organic farming systems and 5 ha to conventional. The justification for this plan was not clear.

At my University farm on Roseworthy Campus, South Australia (area of 1,700 ha) we have had similar discussions on allocation of land to a range of options. Always there is the problem of balancing teaching and research needs with the need to maximise profitability. We have developed a matrix concept to help structure competing demands for land (see Table 1 below). This matrix can be adapted to suit local needs. Also, a recent concept was to set aside part of the farm as a purely commercial enterprise with profits from the farm supporting a unit set up purely for teaching and research. This concept has merit in physically separating the ongoing dilemma between teaching and research on one hand and commercial profit on the other.

Table 1. Example of a matrix approach to resolving land use conflicts on University farms. Other columns can be added as needed.

Enterprise	Relevant to local environment?	Industry support?	Potential for attracting research income?	Strategic advantage for University?	Etc…
Wheat	yes	some	yes	yes	
Wool	some	yes	yes	yes	
Dairy	no	no	some	some	
Viticulture	no	no	some	no	
Etc…					

15-17 October, Talca

Attend the XXVIII Annual Meeting of Chilean Society of Animal Production and present invited review paper.

I will not comment in detail on the content of the conference. The conference was well organised with plenary sessions, concurrent sessions, and poster sessions. There was a very enjoyable social program and it was clear that Chilean scientists enjoy their networking. The Chilean Society of Animal Production conducted an excellent awards night and it was obvious that this society is well managed and supported.

Within the constraints of my very limited Spanish language skills it was obvious that there was good research being carried out on pasture and animal production. There appeared to be some excellent pasture ecology research in progress. There was a strong focus on increasing productivity and in targeting quality products suitable for export markets. Compared to equivalent Australian conferences there was a lack of papers on sustainability issues and few papers that attempted to work with farmers on local production issues.

18 October, Talca

Visited an intensive feed lot enterprise that is in the process of converting from dairy to export beef production. The dairy feed lot appeared to be very efficient, utilising local waste feed stock from the export bean and corn industry. Despite these feed efficiencies, dairy was not profitable due to low milk prices. As dairy industries around the world reduce subsidies and expose farmers to low world market prices many farmers have been forced to consider alternative enterprises.

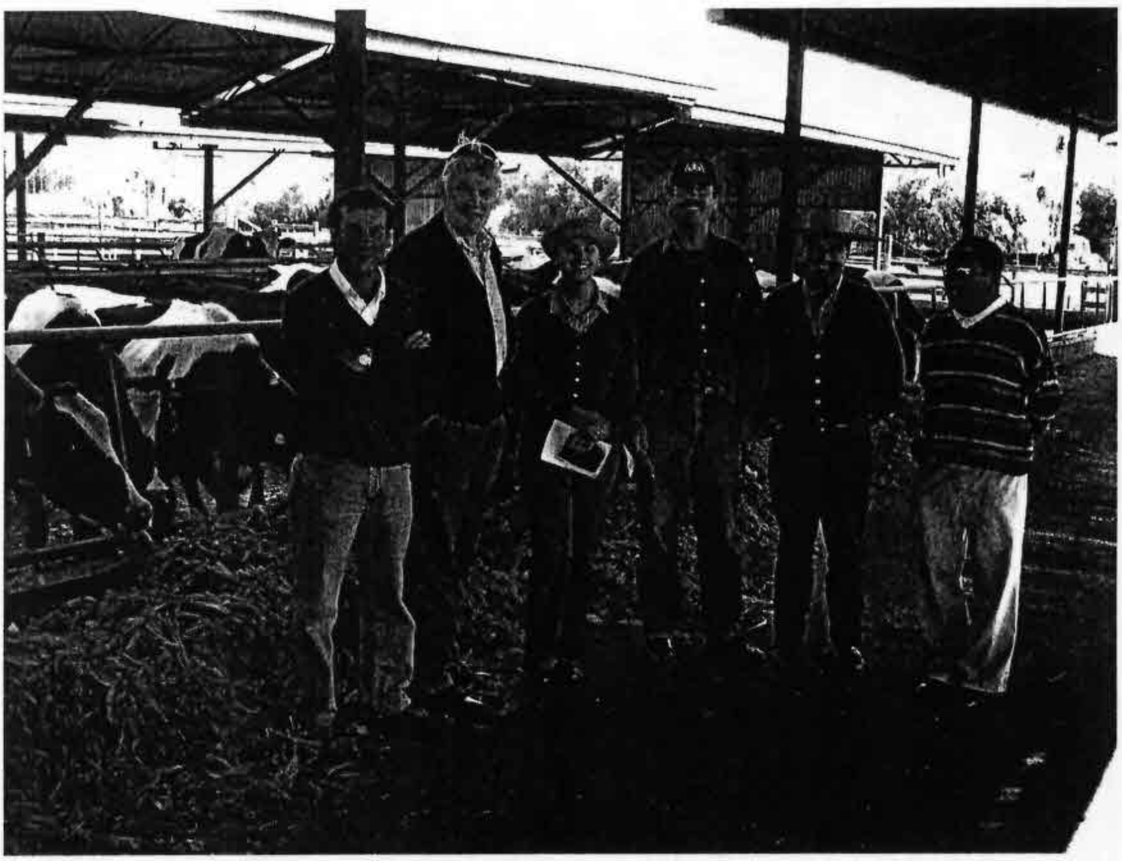

Plate 1. Talca dairy feed lot showing frozen vegetable export waste material as feed stock.

Inspected high-yielding faba bean crop. The crop is hand harvested and the beans are processed as frozen export vegetable. Corn is also locally produced for the frozen vegetable export market.

A typical rotation on this farm was 5-6 years of lucerne followed by a single maize crop and then return to lucerne. Lucerne yields under rainfed conditions were 12.5

t/ha of dry matter from 5 harvests per year. Fresh weight of maize was around 110 t/ha.

This farmer reported no real concerns with the sustainability of his farming system. His main concern was low profitability despite impressive productivity.

The second farm visited followed a traditional rotation of 4-5 years of pasture, followed by wheat, then maize. The irrigated pasture consisted of tall fescue and white clover and was normally very productive and persistent. The older father on this farm regretted the current shift to more intensive cropping at the expense of pastures and livestock. His middle-aged son was happy with the more intensive cropping as profits were higher than for livestock. He reported no problems with continuous corn cropping over 5-6 years. His crops included transgenic corn for seed production.

Again, these farmers reported no real concerns with the sustainability of their farming system. What they were interested in was a comprehensive comparison of the profitability of intensive cropping systems versus the more traditional pasture-crop farming systems.

20 October, Valdivia

I inspected two University of Valdivia farms at Valdivia. The first farm featured an experiment comparing the productivity and persistence of a native grass (*Bromus valdivianos*) with the traditional introduced pasture of perennial ryegrass and white clover.

The problem with the introduced pasture mix is that the the sown species do not persist well and after 4 years these pastures become dominated by weedy species and productivity declines. When the native *Bromus valdivianus* is fertilised and grazed correctly it is as productive (12 t/ha of dry matter) as the introduced pasture mix but it is more persistent. This is an exciting finding and the research team should be encouraged to develop and exploit this native grass.

Plate 2. Dr Ruben Pulido inspecting a comparison of fertiliser inputs on productivity and persistence of *Bromus valdivianus* and perennial ryegrass. Low fertiliser, weedy pasture on left.

Further research is needed to determine the nutritive value of *B. valdivianus*, develop grazing management guidelines, determine compatibility of the grass with a range of pasture legumes, measure animal productivity, and select superior genotypes for release as commercial cultivars.

The second visit featured an experiment comparing the energy balance of dairy cows grazing pasture with and without supplementary feeding. The issue was how effective are supplements (barley and/or sugar beet) in improving the efficiency of conversion of pasture intake. A feature of the pastures was the very low legume content (<5%) and this was attributed to the low pasture utilisation levels (around 40%) that allow the grass to dominate legumes. In Australia or New Zealand, pasture utilisation rates are normally higher and legume content is also higher.

21 October, Temuco

Visited farm of Mr Arturo Garcia. A typical rotation consisted of wheat/lupin/wheat/wheat or oats. Problems with this fairly wheat intensive rotation included herbicide resistant annual ryegrass weeds and root and foliar diseases in wheat and lupin. Very impressive wheat grain yields of 6 t/ha. Faba bean, field peas and chick pea grow well but there is no market for the grain. A developed market for grain legumes would greatly assist farmers to practice more diverse rotations.

This farmer had very productive irrigated pastures of perennial ryegrass/white clover/oats that were block grazed to achieve higher utilisation levels. The balance of grass and legume looked ideal. A two year old irrigated stand of lucerne (cv.

Rebound) looked very clean and productive. The lucerne is cut three times and grazed in autumn. Annual production is around 12-15 t/ha dry matter and the farmer expects the stand to be productive for around five years.

Plate 3. Two-year old stand of lucerne (cv. Rebound). Left to right, ?, Sergio, Oriela, Dr Adrian Catrileo Sanchez, and local farmer Mr Arturo Garcia.

The next stop was Mr Alex Webber's farm where a naturalised stand of serradella (*Ornithopus compressus*) has caught the attention of the local farmers and researchers. It is thought that this genotype was introduced around 50-60 years ago and has persisted to this day. Research has shown that the local genotype is different to the common Australian cultivars of serradella. Mr Webber has observed that the serradella outperforms sown sub clover based pastures. An advantage of serradella in this environment is that it produces more dry matter in November and December, possibly due to a deeper root system than sub clover. Dry matter yields of 7 t/ha have been recorded and pod yields of 1 t/ha have been achieved.

Plate 4. Dr Adrian Catrileo Sanchez and local farmer Mr Alex Webber inspect a stand of naturalised serradella.

New research is about to commence to compare the performance of this local genotype with Australian cultivars of serradella, pink serradella (*Ornithopus sativus*), and biserula (*Biserula pelicinus*). Research is also needed to improve seed harvesting, dehulling, and establishment methods.

22 October, Chillan

Visited a large (1,100 ha) farm 30 km east of Chillan. Inspected beef feed lot operation, perennial ryegrass/white clover pastures and lucerne. A typical rotation was six to seven years of pasture/corn silage/wheat/barley. The pasture produces around 12.5 t/ha, corn silage around 30 t/ha dry matter, and wheat grain 6.5 t/ha. Another rotation practiced was four to five years of lucerne/ annual ryegrass/corn/wheat.

Plate 5. Inspecting new stand of lucerne (cv. WL316HQ). L-R. Dr Marcelo Doussoulin Guzman, Mr Jaime ? (Managing Agronomist), Mr Daniel Troncoso, Mr Nicolas Latalier (Veterinarian), Dr Carlos Orvalle.

In general this farm looked very well managed and highly productive. A concern of the manager was the long-term implication of irrigation with feed lot effluent on soil quality. This is a complex issue and could have wide implications for a lot of producers using effluent irrigation. It is part of a bigger question of irrigation management and water use balance of irrigated faming systems. During my visit I was surprised by the lack of research in this area. Either the research has not been done or many researchers are not aware of the research. If the research has not been done then there is a great opportunity to do some good research in this area. If the research has been done then there is a need to communicate the findings more effectively.

In transit from Chillan to Curico, we inspected a University property near Parral. Here we saw an excellent opportunity for research aimed at improving productivity of local pastures. The local pastures on this farm are representative of many low production farms found on the smaller and poorer farms. These pastures are low in soil phosphorus but contain a diverse legume flora. An experiment conducted alongside local landholders combing P fertiliser with grazing management could demonstrate a cost effective way to improve productivity and profitability on these lands. I have seen this process succeed in Australia, Syria, and China, and I believe it will work in Chile.

<u>23 October, Curico</u>

In Curico we visited two farms belonging to Mr Enrique Frohlich and Mr Guido Besoni. The main enterprise on the first farm was a dairy that produced specialist local chesses. The main issues were profitability and compaction of soil by animals. The farmer complained that most research was not relevant to his circumstances. The second farm was devoted to a feedlot for export beef. Here again the main issue was profitability. This farmer grows corn as a monoculture and does not report any problems with this system producing around 20-30 t/ha of corn silage dry matter. Effluent from the feedlot is spread on part of the farm and the bulk is sold to local horticulturalists as a fertiliser. He reports no concerns for the sustainability of his farming system but I can not help but think there are problems with his monoculture and with his practice of effluent spreading. Some targeted research is needed to confirm or allay these concerns.

Comments on small-holder farming systems

During my journey to official farm visits we often passed through farming land that was described as small-holder farms. These farms are often 10-20 ha in size and poor farmers work this land for subsistence agriculture and some cash cropping. In the Temuco area these small-holder farms occupy as much total land area as the larger, wealthier, more productive farms that I inspected. The individual farms being much smaller, obviously there are many more small-holder farmers in the region than the large wealthy farmers.

A striking feature of the small-holder farms is the low level of crop and livestock productivity per hectare compared to that achieved on the larger, wealthier farms. This is despite numerous research projects that have clearly demonstrated large potential gains in productivity. Clearly there is a large opportunity to raise the productivity and profitability of the small-holder farmers from their current low status.

A prerequisite for this research to succeed is a deep understanding of the current socio-economic status of these farmers. Therefore, initial research should involve socio-economists with the aim of developing a rich picture of the current constraints and opportunities available to these farmers. This initial survey phase of the research naturally leads into a phase where agronomists can work alongside farmers to adapt new technologies into traditional farming systems. One approach to this phase of the research has been described as Participatory Action Research (PAR). PAR is characterised by acknowledging farmers, extension workers, and researchers as partners in the research process. The research is conducted on-farm, and managed by farmers. Farmers are involved in identifying research priorities and in this way the research is relevant to the needs of local farmers and adoption of research is generally improved.

Unfortunately, my itinerary did not include any inspections or discussions with small-holder farmers. So my impressions above are gleaned from discussions from research staff. The fact that my itinerary did not include visits to small-holder farmers is symptomatic of the manner in which the needs of small-holder farmers are dealt with in Chile. My understanding is that there is a separate Ministry within the Government charged with servicing the needs of the small-holder farmers. This structure may hinder the transfer of appropriate agricultural technology to the small-holders as most of the staff with the required technical knowledge and skills are located in the Ministry of Agriculture. As an outsider with limited knowledge, I could be misinterpreting the situation, but I believe there is a very exciting research opportunity to raise the productivity and profitability of small-holder farmers. This research opportunity would involve working closely with small-holder farmers, on their farms, in a participatory style, to firstly understand their unique situation and constraints, and with this knowledge adapt previous research findings to suit their resources. Elements of this research approach are described in Altieri (2002) and McCown (2001).

Recommendations

Enhance exchange of crop and pasture plant germplasm

Because of similarities in climate, there is already a high degree of exchange of agricultural plant germplasm, at least on a commercial scale. Most of the pasture legumes and grasses used in Chile are sourced from either New Zealand (higher rainfall environments) or Australia (lower rainfall environments). The one exception to this general rule was alfalfa, where most germplasm was sourced from the United States of America.

However, most of the Australian cultivars I saw in Chile were older cultivars that in Australia have been replaced with newer superior cultivars. This may be because the old Australian cultivars outperform the newer Australian cultivars under Chilean conditions, or the Australian pasture seed export industry is not promoting the latest cultivars to the Chilean importers.

> Recommendation 1: Chilean pasture scientists to receive adequate funding to allow them to establish an ongoing regional pasture evaluation program. This program would import the latest germplasm from relevant local and international sources and evaluate the material in a network of carefully targeted and managed sites to cover the major soil, climate, and socio-economic farming systems present in central and southern Chile. Financial support for this initiative could come from a combination of government, industry (seed merchants etc.), and farmer levies.

Although I have focussed on pasture plant germplasm, the same argument could be applied to crop improvement programs in Chile. Presumably some formal arrangements are already in place to achieve the goal of delivering the best available germplasm to Chilean farmers in a timely, efficient, and equitable manner.

Currently in Australia there has been increased investment in evaluation of a wide range of pasture plant germplasm to address the dryland salinity threat. Some of this material may be relevant for specific niches in Chile where pasture plants may have a role in repairing degraded environments or in preventing degradation from occurring. Evaluation of this material should be seen as a separate activity to the mainstream pasture plant improvement evaluation described in Recommendaton 1.

Recommendation 2: A multidisciplinary team comprised of pasture agronomists, soil scientists, economists, and social scientists be formed to investigate the need for pasture plants for environmental remediation in Chile. Depending on the outcome of their feasibility study, seek funding to establish a network for regional evaluation and management of new pasture systems. Note that there is a duty of care to include assessment of weed risk potential when importing non-traditional pasture species.

Finally, it should be acknowledged that germplasm exchange will be a two-way interaction. The native and naturalised flora of Chile undoubtedly contains genotypes with commercial potential in foreign countries including Australia. Historical examples include the naturalised *Medicago polymorpha* genotypes collected in Chile and exploited commercially in Australia as cv. Santiago and cv. Serena. During my visit I witnessed a naturalised stand of serradella (*Ornithopus compressus*) that was outperforming imported Australian cultivars of subterranean clover. In the high rainfall environment of Valdivia, the native grass *Bromus valdivianos* is outyielding and persisting better than imported New Zealand grasses. These few examples illustrate the potential of the native and naturalised flora and this material should always be included in evaluations of imported germplasm.

Recommendation 3: Research to systematically evaluate and exploit the native and naturalised flora should be supported. This research should be funded by those who will benefit from the potential productivity gains, and also by those in the wider society interested in maintaining and promoting biodiversity.

<u>Agronomy for sustainable agricultural systems</u>

I will discuss agronomy under two headings based on the contrasting socio-economic farming systems present in Chile.

1. Large, high-input commercial farms.

The farms I visited in Chile were all in this category. They are characterised by relatively large area 100 to >1,000 ha, high inputs of labour, machinery, irrigation, fertilisers, tillage, and are generally highly productive.

From an Australian perspective the use of irrigation water seems wasteful and inefficient. Fortunately Chile is blessed with generous water resources for irrigation. In most years there is adequate supply of water although shortages have occurred in recent years. In Australia, irrigation water is scarce and great attention has been given to improving water use efficiency and reducing negative off-site impacts of irrigation such as soil and groundwater salinity, nitrate leaching, and pollution of groundwater resources. In Chile there seems to be only a small awareness of the potential for environmental degradation resulting from inefficient irrigation practices.

Recommendation 4: Fund, design and implement detailed case studies on the hydrological balance of key representative farms. The aim of these case studies would be to partition the water balance into its key components (rainfall, irrigation, evaporation, transpiration, runoff, drainage, soil water storage) for a range of representative situations. Related issues such as nitrate leaching and salt dynamics could also be included in this research. This research is complex and expensive to conduct. There must be realistic funding, strong leadership, multidisciplinary teams, and land manager involvement.

Another feature of the local agriculture was the high frequency and intensity of soil cultivation. Bare fallow was common and tillage implements included disc ploughs and deep delving tyned implements. In Australia and throughout the world there is a trend towards reduced or even no-tillage farming. The benefits of reduced tillage, sometimes called conservation farming, include reduced soil erosion, improvement of soil fertility, maintained or increased grain yield, and reduced input costs. However, these benefits may not translate to the specific characteristics of Chilean agriculture.

Recommendation 5. Review existing research comparing reduced and no-tillage crop establishment systems with traditional cultivation systems. Depending on this review, recommend a program of research aimed at demonstrating the benefits of conservation farming to local farming groups. The research team should involve agronomists, soil scientists, economists and local farmers.

Another feature of these high-input, high-production systems was that they were not always high-profit systems. An example was the feedlot dairy system that was in the process of converting to a feedlot export beef system. It is important that all agronomic research include an economic analysis of the existing and proposed new system.

2. Small, low-input subsistence farms.

These farms are characterised as small (5-20 ha), low-input, low productivity, subsistence farms. Usually they are located on the poorer land not selected by the early settlers. A high proportion of these farmers are native Mapuche people. Unfortunately, I did not meet any of these farmers or inspect their farms. This is despite the fact that in some areas, eg. Chillan, these farms occupy a similar proportion of the total landscape as the larger, wealthier farms.

Despite not visiting these farms or meeting the farmers, I did have opportunity to discuss their situation with a number of pasture scientists who had some experience on these lands. It is clear that the current level of productivity on much of this land is extremely low. It is also clear that the potential to increase productivity is very great with dramatic increases in pasture and animal productivity reported in several studies. These increases have been achieved by applying existing knowledge in pasture and animal technology. The potential therefore exists for a large increase in productivity over a large proportion of the landscape and this is a very exciting prospect with the promise of excellent returns on research funds invested in this area. However, the socio-economic situation is complex and many barriers to adoption, some well known and others not understood, exist.

Recommendation 6. A multidisciplinary team, led by social scientists, and including agronomists, animal scientists, soil scientists, and economists, be formed to develop a business case for investing in improving the productivity, sustainability, and profitability of small, low-input farms. This business case should include proposals for investment in specific regions and commodities. The proposed investment should be supported by relevant research and demonstration of improved production systems. The issue of relevance to be determined by a broad group of stakeholders, including the farmers expected to implement the proposed changes. The criteria for investment must include financial return but should also consider environmental concerns, social equity, and maintenance of traditional culture.

Arising from this broad and far-reaching initiative would be a number of specific new industries or farming systems that would need to be demonstrated in specific regions under the management of local communities. The following is just one example.

Current animal production is very low due to low productivity of unimproved pastures and poor animal husbandry. Research has shown that the application of phosphorus fertiliser and introduction of well-adapted, inoculated pasture legume seed increases the production and quality of feed on offer for grazing animals. The increased pasture production can support higher animal stocking rates and allow conservation of fodder for feeding during the dry summer months. The end result is increased sale of animal products and greatly increased enterprise profitability. Why is this system not adopted more widely?

The answer to this question requires socio-economic expertise. The way forward is to work closely with the land holders that are expected to implement the proposed new system. Their concerns and constraints must be taken into account in adapting the new system to their unique situation.

Develop capacity for simulation of agricultural systems

In Australia agricultural system simulation tools have gained widespread acceptance among scientists, extension workers, farmers, and policy makers. Two systems I have experience with are APSIM and GrassGro.

APSIM (Agricultural Production Systems Simulator) was developed in Australia to assist understanding and management of farming systems. The program predicts crop and pasture yield, soil water and soil nitrogen dynamics, and profitability. The program requires inputs of daily climate, a range of soil parameters describing availability of soil water and nitrogen, and detailed crop parameters describing growth and development of the crops and pastures of interest. The program is used in agricultural research into crop and pasture varieties, fertiliser management, irrigation scheduling, crop and pasture rotation studies, and climate risk assessment.

GrassGro has also been developed in Australia as an aid to the management of grazing enterprises. Pasture and animal production and enterprise profitability is predicted from daily climate data, soil parameters, and pasture and livestock parameters describing the particular pasture and animals in question. GrassGro is well suited to optimising grazing systems and for optimising the supplementary feeding of grazing livestock. GrassGro is also well suited to predicting animal growth in a feedlot situation and can be used to optimise the integration of pasture and feed resources to produce a specified animal product to market by a nominated date.

These simulation models have captured a huge amount of Australian and international research knowledge and are the result of a large investment of research funds in Australia. The opportunity exists for a research and/or education organisation in

Chile to capitalise on this investment by adapting these models to suit local needs. Such a decision would require a long-term commitment by the Chilean organisation to train a group of scientists in use of the models and in developing and applying the models to local issues. The experience in Australia is that progress is best when simulation modelling and experimentation are combined within a multidisciplinary team. Selection of scientists for inclusion in a modelling team would ideally include agronomists, animal scientists, soil scientists, and sociologists. Personal aptitude for systems thinking and conceptualising processes mathematically are also desirable.

> Recommendation 7. An evaluation team be appointed to determine if investment in developing a capacity in simulation modelling would be desirable from a Chilean perspective. This team should be supported to visit Australia to hold discussions with key developers of the simulation systems located in Toowoomba (APSIM) and Canberra (GrassGro). An opportunity exists for this visit to coincide with the 4th International Crop Science Congress to be held in Brisbane in September 2004 where examples of simulation modelling research will be on display.

A complimentary approach to the recommendation above would be for the Chilean government to fund a number of postgraduate scholarships to support Chilean scientists to study at Australian universities to become proficient users of APSIM and/or GrassGro. Such postgraduate study could utilise the 'split program' option where the postgraduate student divides their time between Chile and Australia. In this model, Chilean postgraduates can apply new knowledge in simulation modelling to local Chilean issues as part of their PhD research program.

> Recommendation 8. The Chilean government fund several postgraduate scholarships to allow Chilean scientists to enrol at Australian universities to build human capacity in agricultural system simulation.

Develop participatory research approach with local farmers

A strong trend in recent years in Australian agricultural and land management research has been the planned involvement of end users in the design and implementation of research. In the past research was conducted largely in isolation from the end users and results were 'extended' to the farming community, sometimes with very poor levels of adoption. More recently, farmers and land managers are formally involved in the research planning, implementation, and management of research often located in farmers' fields. Adoption of research from this latter process is often high as farmers 'own' the research and have ensured the research is relevant to their specific situation.

In Australia, a number of nationally coordinated programs have enjoyed considerable success in achieving high levels of adoption of improved farming practices. Notable examples include:

Landcare, a national program for farming in a more sustainable manner.

Topcrop, a program aimed at farmers to adopt best practice for productive and sustainable grain crops.

Sustainable Grazing Systems, a program aimed at graziers to improve adoption of productive and sustainable grazing systems.

All of these successful programs have featured heavy involvement of farmers and landholders in identifying research needs, conducting research and demonstration on farm, and promoting results more widely to other farmers. In Australia the position of farmers is further strengthened by the contribution of farmer levies to Rural Industry Research and Development Corporations that fund much of the agricultural research in Australia.

> Recommendation 9. The Chilean government support a group of Chilean scientists, extension workers, and farmers to visit Australia to see first hand the involvement of farmers in agricultural research in Australia. Such a visit would require a duration of 2-4 weeks and cover several states (New South Wales, Victoria, South Australia) to allow visitors to view Landcare, Topcrop, and SGS programs in action.

The above recommendation could have far-reaching implications for the conduct of agricultural research in Chile. In particular, this recommendation supports in general the more specific recommendations 1 to 8.

<u>Research management and governance</u>

A feature of research funding in Australia is the existence of Rural Industry Research and Development Corporations. These corporations collect levies from farmers based on production from the farm. The levies raised in this manner are then matched on a dollar for dollar basis by the Australian government. R&D corporations exist for the grains industry (GRDC, Grains Research and Development Corporation), meat industry (MLA, Meat and Livestock Australia), wool industry (AWI, Australia Wool Innovation), and soil and water resources (LWA, Land and Water Australia), and others.

Each corporation is governed by a board including farmer, industry, and science representatives. Funds are distributed annually on a competitive basis based on priorities developed by the industry. The funds distributed by the corporations have a strong influence over the direction of other government funding.

Another feature of the Australian research environment is the Australian government Cooperative Research Centre, or CRC, program. The CRC program aims to bring together researchers from universities, national and state research organisations, and industry to focus on a specific issue. Example CRC's include the CRC for Plant Based Management of Dryland Salinity, the CRC for Weed Management Systems, the CRC for Molecular Plant Breeding, and the proposed CRC for Climate Variability and Drought Risk Management.

These CRC's force collaboration through funding and reduce duplication and competition for funds. All CRC's have basic and applied science programs as well as education programs and community outreach programs. The CRC program is not without its critics but many would claim they have been a huge success.

> Recommendation 10. The Chilean government support a group of senior research managers to visit Australia to evaluate agricultural research funding

and management structures. In particular the visit should include the Rural Industry Research & Development Corporations and the Cooperative Research Centre program. Both of these programs are administered out of Canberra but the visit would need to include regional centres to see how the programs are delivered to farmers and land managers.

Itinerary

Date	Location	Activity	Personnel
Fri 10 Oct	Santiago	Arrive from Australia	
Sat 11-Mon13 Oct	Santiago	Adjust to time zone and see the city.	
Tue 14 Oct	Curico	Travel and meet academic staff from Universidad Catolica Del Maule.	Mr Daniel Troncoso
Wed 15 Oct	Talca	Travel and start of XXVIII Chilean Society of Animal Production.	Dr Christian Hepp Mr Victor Valencia Baier
Thur 16 Oct	Talca	Present invited paper to XXVIII Annual Meeting of Chilean Society of Animal Production.	
Fri 17 Oct	Talca	Finish of XXVIII Annual Meeting of Chilean Society of Animal Production. Visit local winery.	Mr Daniel Troncoso
Sat 18 Oct	Curico	Farm visits around Talca and travel to Curico.	
Sun 19 Oct	Curico	Travel from Curico – Santiago - Valdivia	
Mon 20 Oct	Valdivia	Present seminar and inspect Universidad Austral de Chile research farms. Travel to Temuco.	Dr Ignacio Lopez Campbell Dr Ruben Pulido
Tue 21 Oct	Temuco	Inspect farms around Temuco and present seminar at INIA Carillanca research station. Travel to Chillan.	Dr Adrian Catrileo Sanchez Mr Sergio Hazard Torres
Wed 22 Oct	Chillan	Presentation to Agriculture Faculty of Universidad Concepcion, Chillan, and inspect local farms. Travel to Curico.	Mr Marcelo Doussoulin Guzman
Thur 23 Oct	Curico	Presentation to students and local farmers. Universidad Catolica Del Maule.	Mr Daniel Troncoso Mr Jaime Molinos Dyson
Fri 24 Oct	Santiago	Travel from Curico to Santiago.	
Sat 25 Oct	Santiago	Depart for Australia	

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I am grateful for the funds provided by the Chilean Ministry of Agriculture that covered my airfares and living costs while in Chile.

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I wish to thank my employer, The University of Adelaide, for granting me permission to undertake this trip. I am confident that benefits such as collaborative research and postgraduate students will flow on from this study trip.

Lastly I would like to express my appreciation to my wife Melindy and my two daughters, Anna and Sophie, for supporting me to undertake extended work away from my home and family.

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The role of pasture legumes in sustaining productive and efficient cropping systems.

El rol de las leguminosas forrajeras en la mantención productiva y eficiente de los sistemas de cultivos.

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Trabajo presentado en la XXVIII Reunión Anual de la Sociedad Chilena de Producción Animal.
Octubre, 2003

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Resumen

El rol pasado, actual, y futuro de las praderas en sistemas de cultivos australianos de clima templado se discute. Los impactos de las praderas sobre los cultivos sucesivos se discuten junto con los efectos sobre las praderas después de cultivos. La perspectiva histórica revela que el rol de las praderas está variando continuamente en respuesta a los precios de mercado de los productos de cultivos como del ganado, a los avances en el desarrollo de tecnología de los cultivos, y a las amenazas a la sustentabilidad.

Los principales progresos actuales se discuten incluyendo la proliferación de malezas herbicidas resistentes y el incremento de superficie afectada por salinidad de suelos. Ambas amenazas se están solucionando con especial énfasis a través de las praderas como alternativa económicamente viable y ambientalmente sostenible. Este nuevo rol de las praderas combinado con los altos valores actuales de lana y productos cárneos han dado lugar en el presente a un alto nivel de interés en las praderas. Se explica las investigaciones recientes en el desarrollo de nuevas especies y cultivares pratenses para esos propósitos específicos.

Herramientas de simulación de sistemas agrícolas GrassGro y APSIM se describen y su rol en la investigación y el manejo de sistemas praderas-cultivos son analizados. Las praderas seguirán siendo un componente importante en los sistemas australianos de cultivos y su papel futuro estará fuertemente ligado a asegurar la sustentabilidad de estos sistemas.

Introducción

La integración de la fase de pradera al sistemas de cultivos tiene muchas ventajas potenciales y también muchas desventajas potenciales. El sistema es complejo, y plantea muchos desafíos a la toma de decisiones prácticas en el manejo. Los agricultores deben ocuparse de la incertidumbre asociada a un clima altamente variable, fluctuaciones de precio de mercados, y una compleja interacción aún no totalmente entendida entre las fases de cultivos y praderas en una rotación. Esta incertidumbre también plantea los desafíos para la comunidad científica agrícola. La investigación agrícola tradicional es reduccionista por naturaleza, y mientras esta visión es relevante para algunos propósitos, tiene menor importancia para el manejo de sistemas complejos.

Existe un rol, actualmente poco desarrollado, en que las ciencias agropecuarias asista en el manejo de los sistemas agrícolas complejos. En las decisiones diarias de manejo, los agricultores exhiben una capacidad inherente de integrar la información de una amplia variedad de fuentes. La ciencia puede asistir a este proceso capturando el conocimiento del mundo biológico, formalmente integrando y vinculando este conocimiento en un motivo útil, y proporcionando información que es relevante para la toma de decisiones. Un ejemplo de este acercamiento es el desarrollo y aplicación de los modelos de la simulación computacional de sistemas agrícolas. Las características de esta metodología de la investigación incluyen un acercamiento holístico a los sistemas agrícolas, la integración de las distintas ciencias disciplinarias, la importancia a las necesidades de los usuarios finales, y un deseo de trabajar de cerca con los agricultores.

Esta publicación comienza con una reseña del rol tradicional de praderas en sistemas de cultivo. Luego analiza sobre los progresos recientes en precios de productos y las amenazas para a la sustentabilidad que están conduciendo a cambios en la manera que las praderas son integradas con los cultivos. Los progresos recientes en tecnología de praderas, incluyendo la investigación para desarrollar nuevas especie pratenses para propósitos específicos se discuten. La publicación acaba proporcionando dos ejemplos del uso de la simulación de sistemas que se han aplicado con éxito para la toma de decisiones en la investigación y manejos prediales por el agricultor.

Summary

The past, current, and future role of pastures in Australian temperate cropping systems is discussed. The impacts of pastures on following crops are discussed along with the impact of crops on following pastures. The historical perspective reveals that the role of pastures is constantly changing in response to market prices for crop and livestock commodities, developments in cropping technology, and threats to sustainability.

Major recent developments are discussed including the development of herbicide resistant weeds and the expansion in the area affected by dryland salinity. Both of these threats are being addressed with special purpose pastures that are both financially viable and environmentally sustainable. These new roles for pastures combined with current high prices for wool and meat commodities have resulted in a high level of interest in pastures at the current time. Current research into developing new pasture species and cultivars for specific purposes is outlined.

Agricultural system simulation tools such as GrassGro and APSIM are described and their role in research and management of pasture – crop systems discussed. Pastures will remain an important component of Australian cropping systems and their future role will be closely linked to ensuring the sustainability of these systems.

Introduction

The integration of a pasture phase into cropping systems has many potential benefits and also many potential disadvantages. The system is complex, and poses many challenges for practical management decision making. Farmers must deal with a great deal of uncertainty associated with a highly variable climate, market price fluctuations, and complex and imperfectly understood interactions between the crop and pasture phases of a rotation. This uncertainty also poses challenges for the agricultural research community. Traditional agricultural research is reductionist in nature, and while this approach is relevant for some purposes it has less relevance for the management of complex systems.

There is a role, presently under developed, for agricultural science to assist in the management of complex farming systems. In their daily management decisions, farmers display an inherent ability to integrate information from a wide variety of sources. Science can assist in this process by capturing knowledge of the biological world, formally integrating and linking this knowledge in a purposeful manner, and providing output that is relevant for decision making. One example of this approach is the development and application of computer simulation models of agricultural systems. Characteristics of this research methodology include a holistic approach to agricultural systems, integration of science disciplines, relevance to end-users needs, and a desire to work closely with farmers.

This paper begins with an outline of the traditional role of pastures in cropping systems. It then moves on to discuss recent developments in commodity prices and threats to sustainability that are driving change in the ways pastures are integrated with crops. Recent developments in pasture technology, including research to develop new pasture species for specific purposes are discussed. The paper finishes by providing two examples of system simulation that have been successfully applied to practical research and farmer management decision making.

Traditional role of pastures in cropping systems

Farming systems involving the rotation of crops with pastures have been practised in southern Australia since the 1950's (Puckridge and French, 1983). Since these early times the role of pastures in cropping systems has continually evolved in response to commodity prices, technological developments, and threats to sustainability. In this section the history and traditional role of 'ley farming' (rotating self-regenerating legume pastures with cereal crops) in southern Australia is described.

History of ley farming

In southern Australia during the early 1900's the traditional farming system that had been practised since the beginning of agriculture in this country (1850's) consisted of a cereal monocultures, largely wheat, preceded by a long fallow designed to conserve soil water for the following crop. The fallow was maintained free of weeds by repeated cultivation. The practice of fallowing resulted in severe soil erosion by wind and water and was clearly not sustainable.

In the early 1900's the annual legume, subterranean clover, was first noticed growing in the Adelaide Hills, and persistent efforts by an enlightened farmer saw it eventually domesticated as the first commercially available cultivar (cv. Mt. Barker) of subterranean clover in the world. This was the beginning of the Australian obsession with legume-based farming systems.

It was not until the 1950's that adapted annual legume species had been selected and developed for use in the 'wheat-sheep' zone of Australian agriculture (Puckridge and French, 1983). A range of largely subterranean clover and annual medic cultivars were developed for the diversity of soils and climates (average annual rainfall ranging from 250-600 mm) found in the wheat-sheep zone. The introduction of pasture legumes into the cropping zone had a number of benefits. Farmer income was diversified through production of wool from the sheep grazing on ley pastures. Soil fertility was improved through biological nitrogen fixation and organic carbon inputs from the pastures. Soil erosion was reduced by maintenance of vegetative cover and reduction in cultivation. The introduction of annual pasture legumes was widely hailed as an improvement in both the productivity and sustainability of local farming systems.

From the 1950's to the 1980's the focus of pasture research was on increasing the productivity and persistence of these annual pasture legumes. New cultivars of subterranean clover and annual medic were developed with better adaptation to increasingly arid environments. Improved management techniques for establishing, fertilising, and grazing the pastures were developed and extended to the farming community.

From the 1990's through to the present time the role of pastures in cropping systems has come under close scrutiny due to falling livestock commodity prices relative to crop commodity prices. Many growers have responded by intensifying cropping frequency at the expense of pastures. At the same time as farmers intensified their cropping frequency, a series of threats to the sustainability of intensive cropping systems has emerged. These developments are discussed in a following section.

Crop – Pasture interactions

In a pasture – crop rotation sequence, the pasture phase can have many positive or negative influences over following crops (Robson, 1990). Likewise, the crop phase can have positive or negative influences over following pastures. Some of the more important interactions are listed below (Table 1). Many recent developments in sustainable cropping technology (stubble retention, reduced tillage, high N fertiliser inputs) have had an unintended, but significant, negative impact on self-regenerating ley pastures.

Table 1. Important interactions between pastures and crops in a pasture – crop rotation sequence utilising modern cropping technology.

Factor	Process	Influence
	Effects of legume-dominant pastures on crop production	
Nitrogen	N-fixation by pasture legumes, decomposition, mineralisation, N uptake by following crops.	positive
Carbon	High DM production, carbon inputs from shoot residues and roots, decomposition	positive
Structure	Organic matter inputs help bind soil aggregates, reduction in tillage	positive
Disease	Reduction in diseases hosted on grasses, build up of diseases hosted on some legumes.	positive or negative
Weeds	Diverse weed control opportunities, but can be source of weed problems.	positive or negative
Whole farm profits	Income diversification, synergies possible, but requires high level of management skill.	positive or negative
	Effects of modern cropping technology on following pastures	
Rotation	As cropping intensifies, pasture density reduced as legume soil seed banks decline.	negative
Herbicides	Herbicide residues reduce growth of legumes. Spray-topping can reduce pasture seed set.	negative
Tillage	Reduced tillage leaves pasture legume seed on soil surface increasing rate of seed softening.	positive or negative
Stubble	Stubble retention reduces hardseed breakdown, possible allelopathic effects of cereal straw on pasture legume germination and growth.	negative
Nitrogen	Increased rates of N fertiliser on crops carry over to pasture years and remove competitive advantage of legumes over non-legumes.	negative
Livestock profitability	Farmers shift focus to cropping and neglect livestock enterprises.	negative

Two of the more important interactions, biological nitrogen fixation (BNF) and providing a break in root disease cycles, are discussed in more detail below.

Biological Nitrogen Fixation

The pasture legume – cereal rotation is designed around the principle of fixing atmospheric nitrogen in the pasture phase and exploiting the resulting increased levels of soil inorganic nitrogen in the cereal phase. The wheat crop utilises the soil inorganic nitrogen to produce a high-yield, high-protein grain harvest. After the wheat crop, soil inorganic N levels are low and this promotes a high level of BNF in the following legume dominant pasture. Thus soil inorganic N follows a cyclical pattern of accumulation in the pasture phase and exploitation in the crop phase.

The amount of nitrogen derived from the atmosphere by legumes under Australian farming conditions ranges from 0 to almost 200 kg N/ha (Table 2). An approximate 'rule-of-thumb' is that 25 kg of N is fixed for every tonne of legume shoot biomass produced (Peoples et al., 1998). However, this figure increases to 40-50 kg N fixed for every tonne of legume shoot biomass when below-ground N is taken into account.

Table 2. Estimates of biological nitrogen fixation (BNF) from crop and pasture legumes (data compiled from Unkovich et al., 1997 and Peoples et al., 1998).

Species	%N derived from atmosphere		Total N fixed (kg/ha)	
	Mean	Range	Mean	Range
Subterranean clover	82	0-100	92	0-188
Annual medic	71	7-90	na	na
Lucerne	na	42-71	na	47-167
Field pea	68	31-95	83	26-183
Chickpea	60	37-86	70	43-124

The level of mineral N in the soil profile in the autumn following a productive legume pasture can be enhanced by 100-200 kg N/ha compared to a grassy pasture or fallow. This amount of mineral N is sufficient to meet the N demand of a following crop without further N fertiliser input.

Breaking disease cycles

Another important traditional role for legume pastures was to break the life cycle of cereal root diseases. Volunteer grasses in the pasture (*Lolium, Hordeum, Vulpia* spp.) host root diseases that infect following cereal crops. Major diseases include Take-all (*Gaeumannomyces graminis* var. *tritici*), Rhizoctonia Bare Patch (*Rhizoctonia solani* AG-8), and Cereal Cyst Nematode (*Heterodera avenae*). McNish and Nicholas (1987, Figure 1) provide an example of the relationship between grass content of the pasture and disease incidence in a following wheat crop. Largely for this reason, grasses in ley pastures have often been regarded as weeds and the advent of grass-selective herbicides in the 1980's was seen as a saviour for farmers wanting to maximise crop production following pastures. In hindsight, grass-selective herbicides were poorly utilised as they quickly led to the development of herbicide resistant grass weed populations. The management of these herbicide resistant weed populations is discussed in a following section.

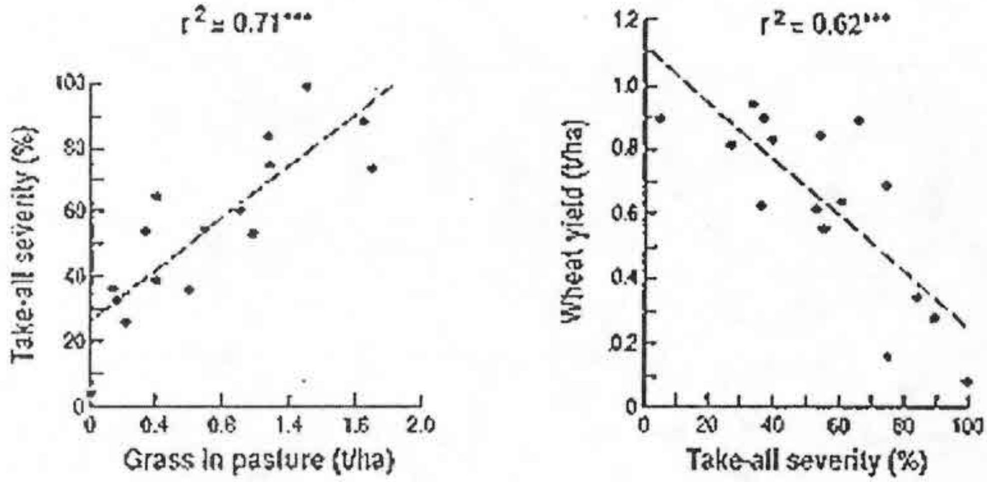

Figure 1. The relationship between pasture grass composition, disease incidence and grain yield in a pasture – crop rotation (McNish and Nicholas, 1987).

In addition to the aforementioned cereal root diseases that are hosted by grasses, diseases such as Bare Patch (*Rhizoctonia solani*) and the Root Lesion Nematode (*Pratylenchus* spp.) can build up in a grass-free pasture. We now know that annual medics (*Medicago* spp.) can host these diseases and that under a rotation of wheat – medic pasture these diseases can build up and significantly reduce crop yields.

Emerging role of pastures in cropping systems

Managers of farming systems continually adapt to the prevailing economic and biological conditions. For example, the relative profitability of livestock versus crop commodities exerts a strong influence over the balance of pasture and crop area on a mixed enterprise farm (McCown et al., 1988). Other forces for change are threats to the sustainability of current farming systems. Short-term decisions to practice a farming system aimed at optimising profit may not be sustainable in the medium- to long-term. Recent examples include the development of herbicide resistant weeds and the spread of dryland salinity.

Recent challenges to the traditional ley farming system

During the 1990's the price of wool has been low relative to historical levels (Figure 2). A combination of declining sheep numbers, drought, and no wool stockpile has resulted in current wool sales being around 50% of the long-term average of around 3.5 million bales per year. During this decade farmers have increased their cropping area at the expense of pastures however pastures remain an important component of the landscape in most agricultural regions. In recent years (since 2000), wool and meat prices have increased and the current profitability of livestock commodities is driving renewed interest in pasture technology.

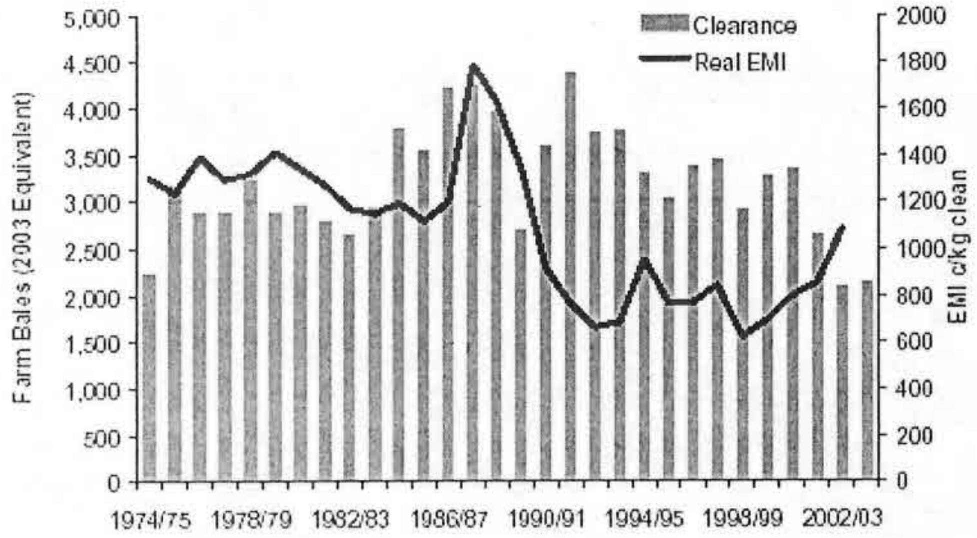

Figure 2. Historical wool prices (Eastern Market Indicator, EMI) and clearance of wool bales (Anon, 2003).

It is clear that the level of interest in, and the area of, pastures will rise and fall in response to economic and biological threats and opportunities. What is important from a pasture research perspective is that a range of flexible pasture technology is available and relevant to meet future challenges and opportunities.

Managing herbicide resistant weeds

Herbicide resistance has developed in a number of weeds worldwide and Australia has the unfortunate distinction of being one of the leaders in the development of herbicide resistance. Herbicide resistant annual ryegrass (*Lolium rigidum*) was first identified in Australia in 1982. The development of herbicide resistance followed closely behind the commercial availability of grass selective herbicides and coincided with an increase in cropping intensity throughout much of Australia. Herbicide resistance has been confirmed in a number of other grass and broadleaf weeds. In 1999, glyphosate resistant annual ryegrass populations were discovered in several Australian states. Herbicide resistant weed populations are often considered by farmers to be their most serious management challenge and many farmers have been forced to alter their cropping system in response to weed competition.

Current recommendations for managing herbicide resistant weed populations emphasise the integration of a range of non-selective management options and pastures feature prominently in the options available (Table 3).

Table 3. Current recommendations for managing herbicide resistant weed populations (compiled from Powles and Bowran, 2000).

Management option	Role for pasture phase?
Reduce weed seed bank	
Heavy grazing	Yes
Spray-top with non-selective herbicide	Yes

Hay cut to reduce weed seed set	Yes
Green manure	Possible
Herbicide use	
Use knockdown herbicides in preference to selective herbicides	Possible
Avoid using high-risk herbicides (Group A and Group B) in pastures.	Yes
Rotate herbicides from different groups.	Possible
Non-chemical weed management options	
Cultivation	Possible
Delay sowing time to control late emerging weeds	No
Burn stubble and/or pasture residues	Possible
Collect weed seeds at harvest	No
Increase crop competition	
Sow competitive crop species and cultivars	No
Increase seeding rate	No
Band fertiliser with seed	No
Time of sowing	No

A common local practice for farmers with a severe herbicide resistance problem is a pasture phase based on annuals or perennials (eg. lucerne, *Medicago sativa*) of several years with the prime aim of reducing the soil seed bank of resistant weeds to a level where a resumption of cropping is economically viable.

Reducing deep drainage under agricultural systems

The area of dryland salinity is forecast to increase from 5.7 million hectares in 2000 to 17.1 million hectares in 2050 (Anon, 2003). This forecast area represents around 30% of Australia's currently arable land and most of the expansion in area will occur in areas that are currently some of the most productive agricultural land. The cause of this expansion in dryland salinity is the deep drainage or recharge that occurs under agricultural systems based on annual crop and pasture plants. The threat of dryland salinity is so serious that it is forcing a total rethink of our agricultural systems with the imperative of designing systems that minimise or eliminate deep drainage. The challenge is to design agricultural systems that not only have high water use but that are also profitable.

The original native vegetation was diverse and included perennial trees, shrubs and grasses that maintained leaf area throughout the year and used nearly all of the rainfall received. This native vegetation was largely cleared to make way for an agriculture based almost exclusively on annual plants. These annual agricultural plants had a shallower root system and used less water than the native vegetation (Hatton and Nulsen, 1999). The resulting increase in deep drainage has led to saline groundwater rising to the surface in low-lying areas. Once the saline groundwater reaches within 1 m of the soil surface, traditional agricultural production becomes almost impossible.

The long-term solution to dryland salinity lies in reducing recharge by incorporating high water use perennial vegetation back into the agricultural landscape. This can be achieved by planting trees or perennial forages over much of the landscape currently dominated by annual crops and pastures. One of the success stories of this research is that the water use of lucerne (*Medicago sativa*) is similar to the native vegetation under many conditions found in the cereal-livestock zone.

Lucerne can be incorporated in agricultural systems in several different ways and this flexibility is part of its attraction to farmers. Lucerne can be utilised in long-term pastures for extensive grazing. In the cropping zone, a phase of lucerne followed by a phase of cropping, so called phase farming, can minimise deep drainage (Dunin et al., 1999). Another option is to grow annual crops over the top of a living stand of lucerne, a special form of intercropping. In this situation the competitive association between crop (eg. wheat) and lucerne can be tipped in favour of the crop through a range of management options such as; suppressing the lucerne with herbicides, promoting the wheat with nitrogen fertiliser, and other practices.

While lucerne is almost the ideal high water use forage crop, it is not well adapted in all soil, climate, or management situations. For example, lucerne is poorly adapted to very acidic soils. The following section discusses the need for increased diversity in forage legumes to meet the requirements of a diversity of farming systems.

Exploiting genetic diversity of pasture legumes

Pasture legumes continue to play an important role in Australian agriculture. Pasture legumes provide high quality feed for grazing livestock, raise soil nitrogen levels, and generally increase productivity in a cost effective manner. Despite the great genetic diversity available in the genus *Fabacea*, only a relatively small number of species have been exploited economically (Table 4). Despite over 60 years of pasture research, only a few species of pasture legumes have been domesticated and made available to farmers as commercial cultivars suitable for the cropping zone (Table 5). In Australia, the area of sown pasture legumes is dominated by just a few species (*Trifolium subterraneum, Medicago truncatula, Medicago sativa*).

Table 4. Genetic diversity available in the genus *Fabacea* and the number of species released as commercial pasture cultivars in Australia.

Genus	Common name	Species in GRIN*	Species cultivated in Australia
Astragalus	Milkvetch	376	1
Biserrula		1	1
Coronilla		24	0
Hippocrepis		14	1
Lathyrus	Chickling	127	1
Lotus		114	2
Medicago	Medics	251	8
Onobrychis	Sainfoin	82	1
Ornithopus	Serradella	12	2
Trifolium	Clovers	371	12
Trigonella		71	0
Vicia	Vetch	190	4

* Genetic Resource Information Network maintained by the USDA.

Until recently, research into pasture cultivar improvement was focussed within the key dominant species with little attention devoted to the so-called 'alternative' species. However, a number of recent, and soon to be released, cultivars have been developed from alternative species, reflecting a shift in research philosophy. The argument for exploiting alternative species is that the traditional species have received around forty years of intense research and future productivity gains may be easier to find in the alternative species rather than continued selection and breeding within the traditional species.

Table 5. Pasture legume cultivars registered* since 1990 for use in cropping systems (Updated from Bellotti, 2001).

Scientific name	Common name	Cultivar name	Agronomic traits	Year registered
Trifolium subterraneum var. *brachycalycinum*	Subterranean clover	Nuba	Replacement for cv. Clare, more productive	1990
Trifolium subterraneum var. *subterraneum*	Subterranean clover	Goulburn	Disease tolerant replacement for cv. Woogenellup	1991
	Subterranean clover	Leura	Disease tolerant replacement for cv. Karridale	1991
	Subterranean clover	York	Productive and persistent replacement for cv. Seaton Park	1995
	Subterranean clover	Urana	Early maturing, hard seed replacement for cvs. Daliak & Dalkeith	2001
Trifolium subterraneum var. *yanninicum*	Subterranean clover	Gosse	Disease tolerant replacement for cvs. Larisa and Meteora	1991
	Subterranean clover	Riverina	Productive and persistent replacement for cv. Trikkala	1996
	Subterranean clover	Napier	Late maturing, low formononetin, disease resistant cultivar.	2003
Trifolium michelianum	Balansa clover	Bolta	Later maturing alternative to cv. Paradana	1998
	Balansa clover	Frontier	Earlier maturing alternative to cv. Paradana	2000
Trifolium resupinatum var. *resupinatum*	Persian clover	Nitro Plus	Early maturing, hard seeded alternative to cv. Kyambro	1998
	Persian clover	Prolific	Early maturing alternative to cv. Kyambro	1998
Medicago	Barrel medic	Caliph	Aphid resistant	1993

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truncatula			replacement for cv. Cyprus	
	Barrel medic	Mogul	Aphid resistant replacement for cv. Borung	1993
	Barrel medic	Jester	Aphid resistant replacement for cv. Jemalong	2001
Medicago littoralis	Strand medic	Herald	Aphid resistant replacement for cvs. Harbinger and Harbinger AR	1997
Medicago polymorpha	Burr Medic	Cavalier	High herbage and high production of soft seed	2002
	Burr Medic	Scimitar	Later flowering than cv. Cavalier.	2002
Medicago tornata	Disc medic	Rivoli	Soft seeded alternative to cv. Tornafield	1990
Medicago hybrid	Disc x Strand	Toreador	Early flowering, aphid tolerant hybrid	2000
Ornithopus compressus	Yellow serradella	Paros	Early maturing, hard seeded alternative to cvs. Madiera and Eneabba	1990
Ornithopus compressus	Yellow serradella	Paros	Early maturing, hard seeded alternative to cvs. Madiera and Eneabba	1990
	Yellow serradella	Charano	More productive and persistent cultivar	1997
Ornithopus sativus	French serradella	Cadiz	Soft seeded and ease of seed harvesting.	1998
Biserrula pelecinus	Biserrula	Casbah	Soft seeded species suited to deep sands	1997
	Biserrula	Mauro	More productive cultivar	2003
Medicago sativa	Lucerne	Quadrella	Disease resistant alternative to cv. Trifecta	1991
	Lucerne	Aquarius	Resistance to phytopthora root rot	1992
	Lucerne	Genesis	Disease and pest resistant alternative to cvs. Aurora and Trifecta	1995
	Lucerne	Sequel HR	Resistance to anthracnose, replacement for cv. Sequel	1998
	Lucerne	Hallmark	Disease resistant	1999

		alternative to cv. Trifecta	
Lucerne	Venus	Disease tolerance for areas prone to waterlogging	2000
Lucerne	Super Ten	Highly winter active cultivar	2002

* Registered as a cultivar by the Herbage Plant Liaison Committee, or granted Plant Breeders Rights under the PBR system.

The argument in favour of exploiting alternative species is easy to justify for target environments where the traditional species are poorly adapted, or where a new threat or opportunity results in a change to the traditional farming system. For example, yellow serradella (*Ornithopus compressus*) has been a huge success on deep acid sandy soils where subterranean clover is poorly adapted. Another example is the increase in the area of dryland salinity that calls for new species in two distinct parts of the landscape with very different specific adaptations. In the discharge areas, pasture plants with specific adaptations to saline and waterlogged conditions are required. In the recharge areas, high water use pasture plants with deep roots and a long growing season are needed to maximise evapotranspiration and minimise deep drainage. Examples of legume species for discharge areas include *Melilotus albus* and *Trifolium fragiferum*, while *Medicago sativa* remains the main option for recharge areas.

Ultimately, a diversity of legume species is required to meet the needs of a diversity of environments and farming systems. This concept is outlined in Table 6. Currently, a priority is to develop species to meet the challenges posed by dryland salinity. This relatively new focus has placed new emphasis on traits such as perenniality, ability to grow roots deep into the soil profile, high water use, salt and waterlogging tolerance.

Table 6. A diversity of legume species to meet the requirements of a diversity of pasture – crop systems.

Legume category	Role in farming system	Key attributes	Example species
Annual pasture legumes	Ley pastures in cropping systems	Productive & persistent under grazing. Regeneration from a soil seed bank.	*Trifolium subterraneum* *Medicago truncatula*
Perennial forage legumes	Phase pastures in cropping systems.	Productive under grazing. Provide management options for pests, weeds & disease. Build soil fertility.	*Medicago sativa*
Annual forage legumes	Green manure or hay crop.	Not grazing tolerant, suited to a hay or silage system.	*Vicia sativa* *Trifolium alexandrinum*

Pulse crops	Grain legume crop as a component of an intensive cropping rotation.	High grain yield. Grain quality.	*Pisum sativum* *Vicia faba*
Legumes for discharge areas	Provide a productive use of saline land for animal production.	Adapted to salinity and waterlogging.	*Melilotus albus* *Trifolium fragiferum*
Legumes for recharge areas	Reduce deep drainage from agricultural land.	Deep root system, long growing season, high water use	*Medicago sativa*

Agricultural system simulation - Science for research and management of pasture – crop rotation systems

The need for system simulation

As research shifts from a production focus to a profit and sustainability focus, there is an inevitable increase in complexity of the system under study. For example, as our focus shifts from increasing crop or animal production to the sustainability of production systems the spatial scale increases from the paddock to the catchment and the temporal scale increases from one to five growing seasons to 20-50 growing seasons. In addition to these increases in complexity of scale, there is increasing diversity in the number of stakeholders with potentially divergent objectives.

One approach to comprehending these increasingly complex systems is through the use of system simulation models. In Australia, this approach has gained widespread acceptance as a tool for research, extension, adult education, and policy advice.

The GrassGro system for simulating animal production from grazed pastures

The GrassGro decision support system is a component of the GRAZPLAN family of models designed to assist managers of livestock enterprises in temperate Australia. A detailed description of the soil water and pasture growth sub-models is provided in Moore et.al. (1997). GrassGro has been designed so that it can be applied to any location in temperate Australia, so the models must be generic in their construction. Different soils, climates, pasture species, and animal species are all accommodated through the use of input or parameter files that are user defined and specific to the particular system being simulated. In theory there is no obstacle to applying the model in another country providing the necessary input data is available or can be collected. The model has been applied in Canada and there is interest in using the model in China.

The GrassGro model runs on a daily time step. Daily climate data (precipitation, solar radiation, maximum air temperature, minimum air temperature, and pan evaporation) are required as inputs. The major components simulated include the soil water balance; pasture growth, utilisation and decay; animal production and reproduction; and enterprise profitability (Figure 3). Management inputs include choice of pasture species, livestock enterprise and animal breed, and the key drivers of profit such as stocking rate, supplementary feeding strategy, time of lambing or calving, and time of shearing. The user must specify costs and prices that are used to calculate the enterprise gross margin.

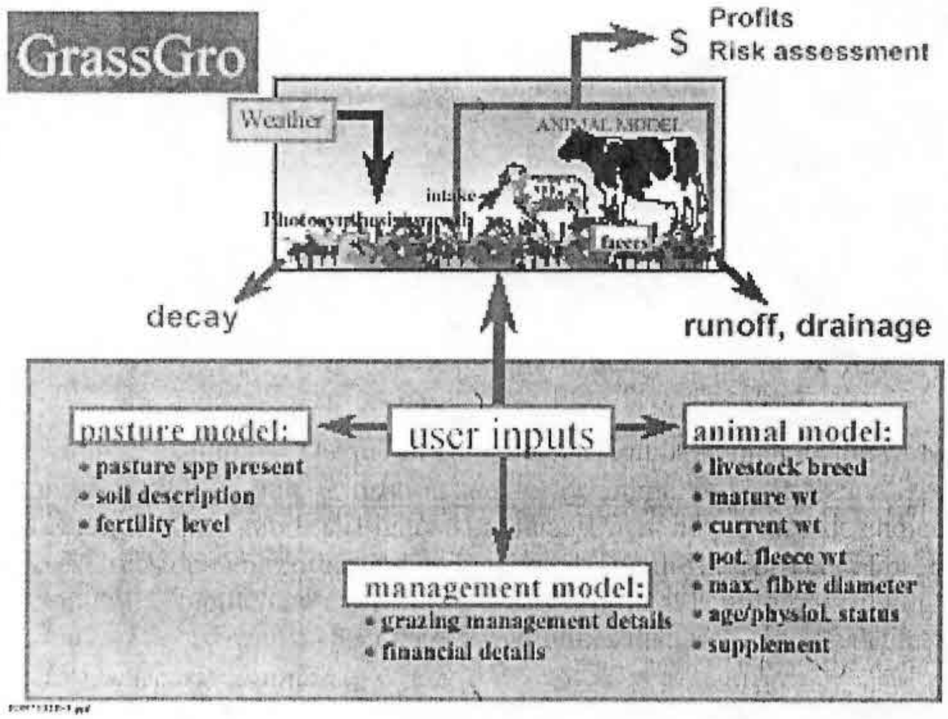

Figure 3. Major components of a grazing system included in GrassGro.

The processes simulated in the pasture component of GrassGro are listed below:
the developmental stages of plant growth (phenology);

- how the plants gain access to light and water;
- conversion of these resources into the products of photosynthesis (biomass);
- allocation of biomass to different parts of the plant;
- changes in the dry matter digestibility (DMD) of plant parts throughout the life of the plant;
- processes of death and decay of roots and of shoots into litter;
- production of seeds and their maturation before the next growing season;
- germination and establishment of seedlings.

In Australia GrassGro is mainly used as an aid for management decisions regarding sheep and cattle production (currently dairy systems are not included) systems. With adequate training the program can be used directly by graziers but often graziers rely on a trained consultant for advice based on GrassGro output. The program is also being used to assist in research planning, and in extrapolating research results beyond the experimental treatments and duration of the experiment (eg. Cayley, et al., 1998). The model has also been used to evaluate policy options, for example, assessing criteria for the provision of government support to drought stricken graziers (eg. Donnelly, et al., 1998) and in assessing pasture plant breeding objectives.

The APSIM system for simulating pasture – crop sequences

The Agricultural Production Systems Simulator (APSIM) is a modelling framework that allows key components of farming systems; soils, climate, crops, forages, and management; to be simulated over time for a specific location. The history, development and application of APSIM have recently been described in Keating et al. (2003). The system can simulate short (one season) and long-term (30+ years) impacts of management on productivity and sustainability. APSIM was designed to combine accurate prediction of crop and forage productivity with long-term consequences of management on soil fertility and water balance. A feature of the system is the high degree of flexibility made possible by the modular structure of the software (Figure 4).

To run a simulation for a specific location the user must supply daily weather data (precipitation, solar radiation, minimum air temperature, maximum air temperature), and specify soil parameters describing plant available water capacity and soil nitrogen and carbon dynamics. Individual crop, pasture or tree species are described by a series of parameters determined from experimental observations. All plant species are described by the same physiological principles and the key processes for wheat are listed below:

- Phenology, thermal time, vernalisation, photoperiodism, development stages.
- Radiation interception, biomass accumulation and partitioning, radiation use efficiency (RUE), grain filling.
- Canopy growth, leaf number, tillering or branching, leaf area, crop height.
- Root growth, root penetration, root length distribution, stress effects.
- Senescence, leaf senescence, biomass senescence.
- Water relations, potential soil water uptake, crop water demand, actual water uptake, water stress factors.
- Nitrogen uptake, potential N uptake, N demand, N uptake, N partitioning, grain N demand, N translocation.
- Crop death.

Modules have been developed for a range of species including; wheat, maize, sorghum, canola, chickpea fababean, soybean, cowpea, lucerne, and a generic pasture. Additional species are being added to the list that can be simulated as needs and resources dictate.

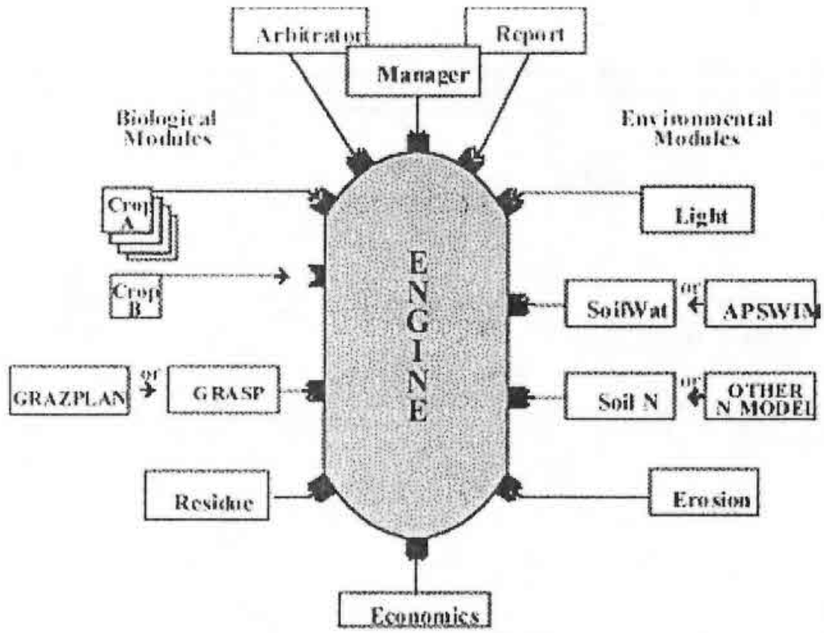

Figure 4. Diagrammatic representation of the APSIM simulation framework demonstrating modular structure that allows specific soil and crop modules to be 'plugged in' to the simulation engine (Anon, 2003).

APSIM has been applied in many faming systems in Australia and internationally (Africa, India, China, Europe). Model applications have been highly diverse ranging from practical on-farm decision making through to broad-scale assessment of land management options. The model has been applied to policy issues such as crop breeding objectives (Hammer et al., 1996), drought assistance criteria (Keating and Mienke, 1998), and climate change (Luo, et al. 2003). A more comprehensive list of model applications is listed below:

- Crop management, N fertiliser, water use, tillage, residue management.
- Water balance, water use efficiency, runoff, evaporation, deep drainage.
- Climate risk, climate change, climate variability, impacts and response.
- Cropping systems, legume-cereal rotations, fallow, cropping strategies.
- Intercropping, competition, resource use efficiency, weeds.
- Land use studies, vegetation options, water balance.
- Soil and water resources, erosion, soil carbon, leaching.
- Crop adaptation and breeding, new crop potential, breeding objectives.

One interesting development is the use of the model in a specific example of participatory action research (PAR). In this approach, simulation modelling is combined with on-farm monitoring of soil and crop or pasture variables to investigate an issue of concern to local farmers. The farmers are included with researchers and extension agents as part of the research team (McCown, 2001). The simulation is specified using the farmer's actual soil properties and climate, and recent management history. The model is then run for a range of management options and farmers are engaged in discussion of model output and implications for their management decisions. Applied in this way, the model facilitates in depth communication between researchers and farmers on agronomy and soil management issues. Farmers learn about the biology of their farming system and researchers learn about farmer decision making processes.

Conclusion

A brief review of the history of ley pastures in Australian cropping systems reveals that the farming system is constantly adapting to influences such as commodity prices, technological developments, and threats to sustainability. The relativity of livestock (mainly wool) prices to crop (mainly wheat) prices has a strong influence on the proportion of a farm devoted to pasture or crop. Technological developments, such as high input cropping systems, have had a significant and largely unintended negative impact on ley pastures in recent years. Threats to the sustainability of intensive cropping systems, such as herbicide resistant weeds and dryland salinity, are forcing many farmers to reconsider pastures in their cropping systems. There are strong interrelationships between these forces for change.

Pastures are currently enjoying a high level of farmer interest due to favourable wool and meat prices, the need to manage herbicide resistant weeds, and the need to reduce deep drainage from agricultural land. Pastures are seen as an important option for developing profitable solutions to the problem of dryland salinity. In areas currently contributing to deep drainage (the recharge zone), high water use pasture plants such as lucerne are seen as the best commercially available option. In areas already experiencing salinity and waterlogging (the discharge zone), pasture based grazing enterprises are once again the most promising commercially viable option. Very different pasture species are needed in the two zones.

Pasture – animal (GrassGro) and soil – crop (APSIM) simulation models are becoming widely accepted among the Australian research and farmer community. These system simulation models have much to offer for research, education, and management of complex farming systems involving the rotation of pastures with crops.

Pastures will continue to play an important role in Australian cropping systems. What is certain is that their role will change in response to the pressures of the day. From a research perspective it is important that a suite of pasture species and technology is available to meet current and future challenges. This objective requires a far-sighted perspective from policy makers in charge of agricultural research funds.

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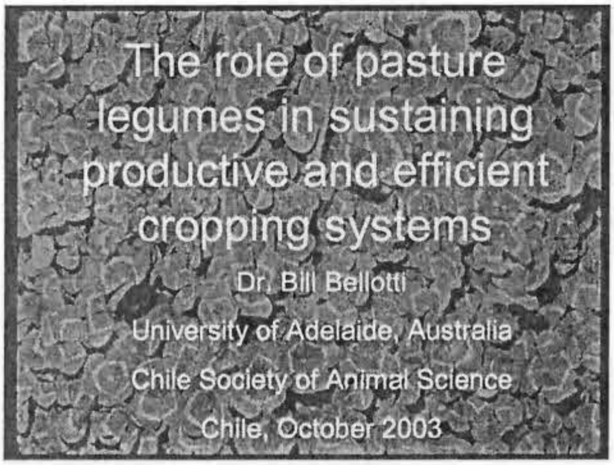
Presentación oral (Power Point) XXVIII Reunión Anual Sociedad Chilena de Producción Animal

The role of pasture legumes in sustaining productive and efficient cropping systems

Dr. Bill Bellotti
University of Adelaide, Australia
Chile Society of Animal Science
Chile, October 2003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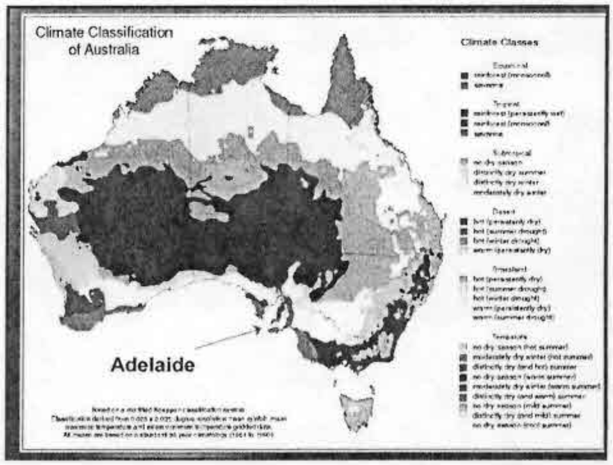
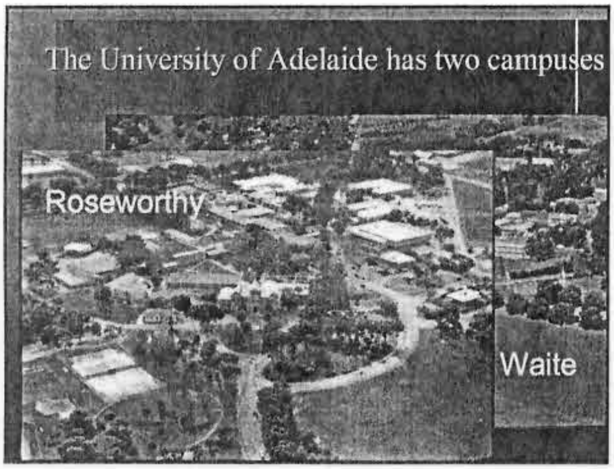
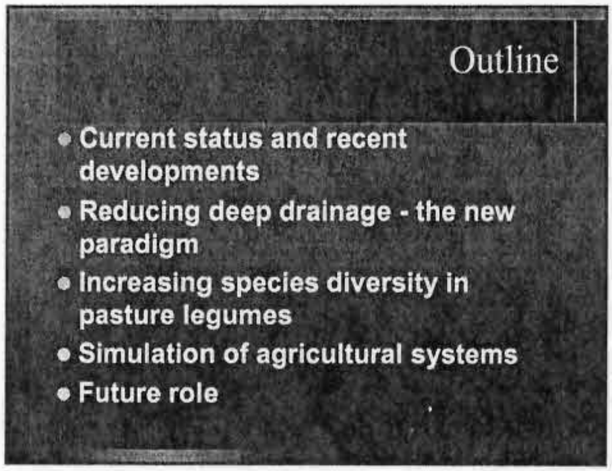
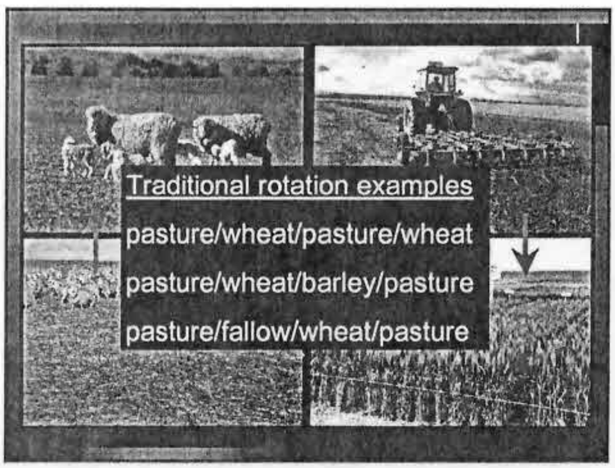
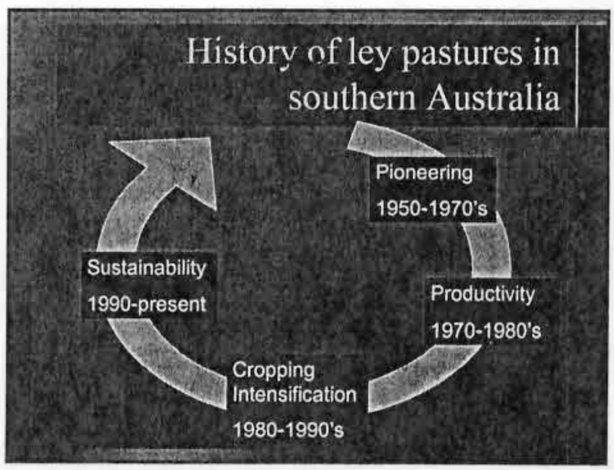

Climate Classification of Australia
Climate Classes
Adelaide


The University of Adelaide has two campuses
Roseworthy
Waite


Outline
Current status and recent developments
Reducing deep drainage - the new paradigm
Increasing species diversity in pasture legumes
Simulation of agricultural systems
Future role


Traditional rotation examples
pasture/wheat/pasture/wheat
pasture/wheat/barley/pasture
pasture/fallow/wheat/pasture


History of ley pastures in southern Australia
Pioneering
1950-1970's
Productivity
1970-1980's
Cropping Intensification
1980-1990's
Sustainability
1990-present

Traditional ley pasture legumes

- annual
- shallow roots
- self-regenerating
- host some cereal diseases

Traditional role of pastures in cropping systems

- Diversify income
  - livestock a… crop co… odit…
- Maintain soil f…
  - biologic…
  - maintenan… structure
- Sustain c…
  - disease and wee…

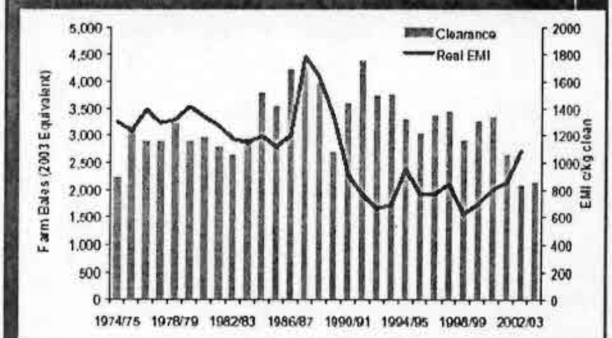
Traditional role under threat

New opportunities emerging

Forces driving change

- Economic pressures
  - low profitability of wool enterprises compared to alternative break crops (pulses and oilseeds)
- Need to maximise crop productivity
  - low crop yield after some pastures
  - root diseases after some pastures
- Threats to sustainability
  - herbicide resistant weed populations
  - spread of dryland salinity

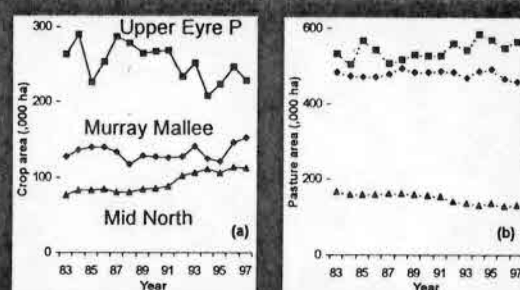
Historical wool prices (c/kg clean wool) 1974-2003



Overall change in total pasture area southern Australia

Area (M ha)	1983-84	1996-97	% change
Crop	14.7	15.1	+ 2.4
Pasture	82.8	82.4	- 0.4

Some substitution of pasture with crop in higher rainfall areas



1980-1990's
"Pastures, the forgotten resource"

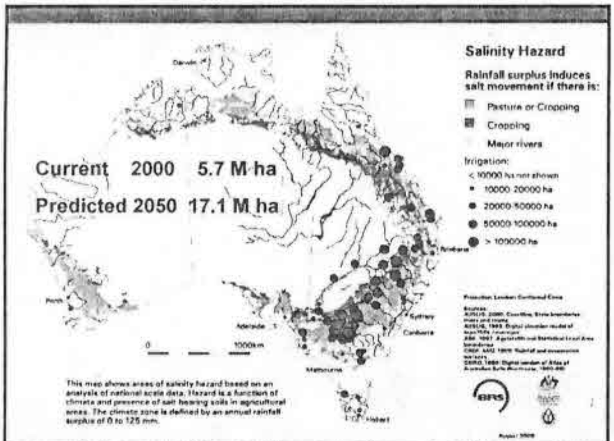
- Despite increases in the area of crop in higher rainfall country, pastures remain an important component on many cropping farms.
- However, farmer expenditure on sowing and maintaining pastures in the cropping zone is very low (average of just $5/ha).
- In general, pasture quality remains well below the potential achievable with existing technology.

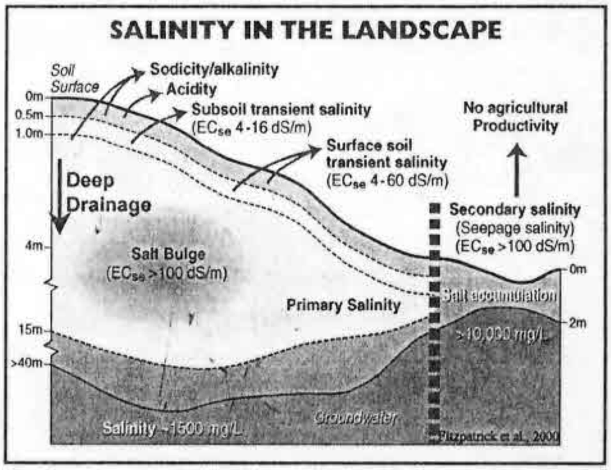
New role emerging

New rotation examples

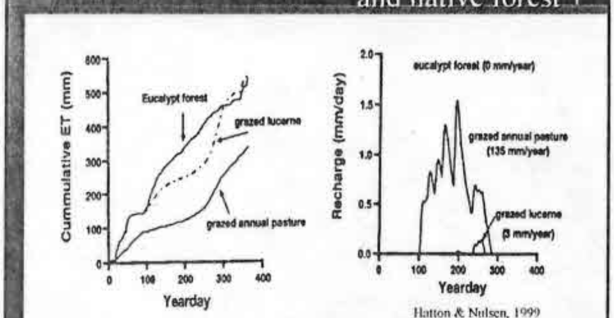
pasture/pasture/pasture/wheat/canola/pulse/barley

lucerne/lucerne/lucerne/4-5 crop years





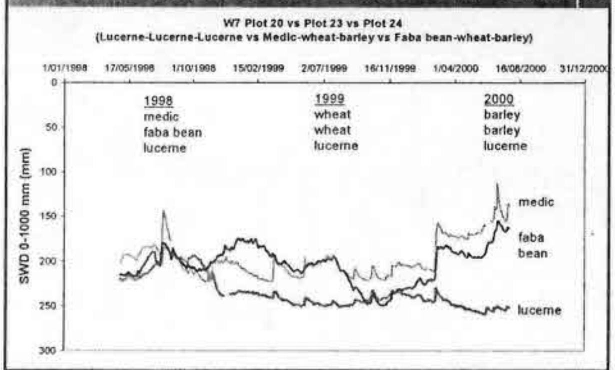
Cumulative evapotranspiration and recharge under annual pasture, lucerne, and native forest



Annual average deep drainage

Location	Deep drainage ($mm\ y^{-1}$)			Reference
	Annual crops	Lucerne	Native vegetation	
Wagga Wagga (NSW duplex)	101-185	2-25	n.e.*	Dunin, et al., 1999
Wagga Wagga (NSW duplex)	135	3	0	Hatton and Nulsen, 1999
Euston - Balranald (NSW Mallee)	6-23	1	1	Kennet-Smith et al., 1994
Upper South East (SA dune system)	50-70	<5	<1	Walker et al., 1992
Moora (WA sandplain)	141[a]	n.e.	15-85[b]	1. Asseng et al., 1998 2. Smettem, 1998

Soil Water Deficit: lucerne vs annuals



Increasing pasture legume species diversity

- Past focus has been on just a few species:
  - *Trifolium subterraneum*
  - *Medicago spp.*
- Current focus is to increase the number of species under evaluation, driven by:
  - economic pressures
  - environmental concerns

Evolving role for ley pastures

- Prepare soil for *productive* crop phase
  - control root diseases
  - contribute to Integrated Weed Management
  - increase soil nitrogen
  - maintain soil carbon & soil structure
- *Sustain* the soil & water resource base
  - minimise deep drainage
  - minimise nitrate leaching

'New' selection traits to meet crop system requirements

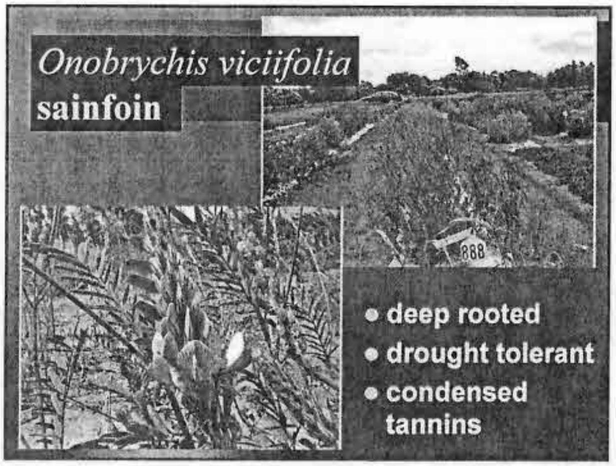
- Non-host for major cereal root diseases
  - *Rhizoctonia* root rot
  - *Pratylenchus* root lesion nematode
- Strong component of IWM
  - good competitive ability
  - herbicide tolerance
- Ability to minimise deep drainage
  - perennial, deep rooting habit
- Ease of establishment and removal

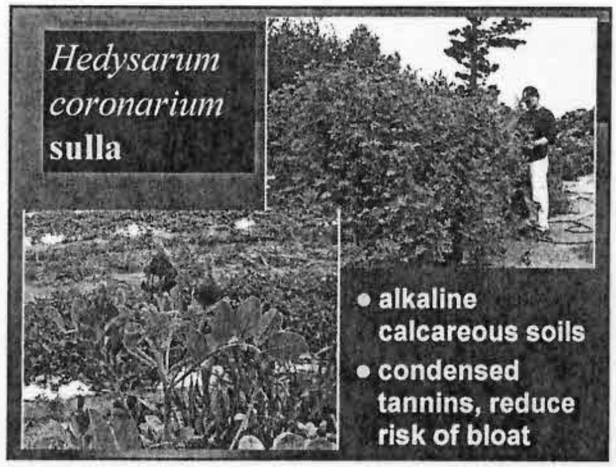
Some examples of alternative pasture legumes

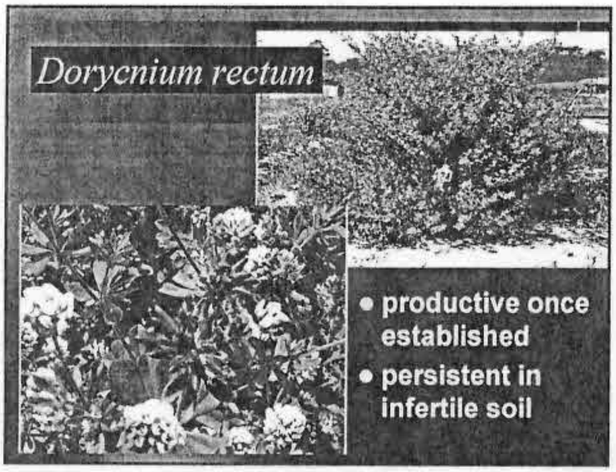
- Annuals
  - *Trigonella balansae*
  - *Trifolium glanduliferum,* gland clover
  - *Lotus ornithopodiodies*
  - *Astragalus hamosus,* milkvetch
- Perennials
  - *Melilotus albus,* sweet clover
  - *Hedysarum coronarium,* sulla
  - *Onobrychis viciifolia,* sainfoin

Melilotus albus sweet clover

- Salt tolerant
- waterlogging tolerant
- productive

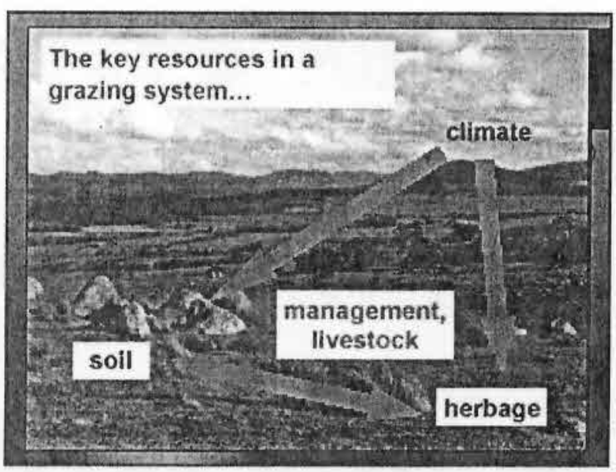


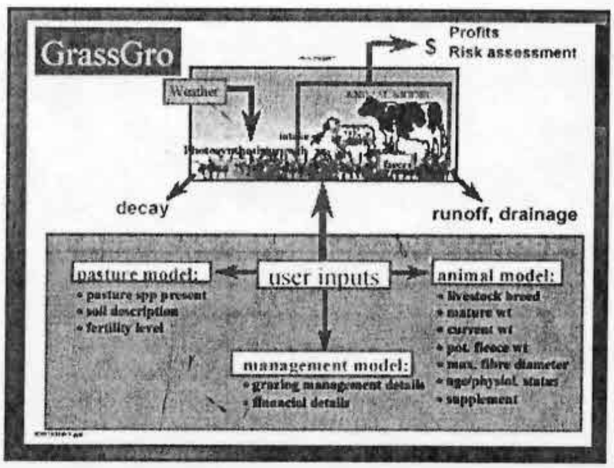




The need for farming systems research (FSR)

- Shift in focus from production alone to production *and* sustainability
- Need to consider spatial and temporal variability
- Need to apply science to *manage* complex agricultural production systems
- GrassGro Decision Support System
- APSIM - Agricultural Production Systems siMulator

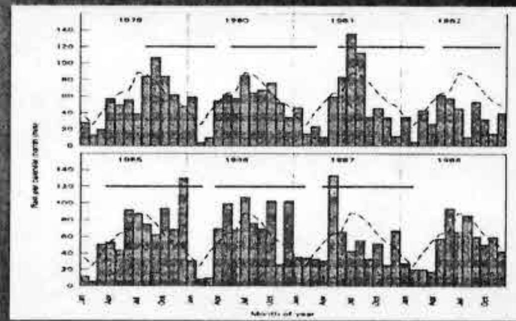




Effect of stocking rate and P fertiliser on pasture and animal production

- P fertiliser by stocking rate (one year old wethers) experiment run from 1979-1987
- focus on pasture production, wool production, profitability
- perennial ryegrass - sub clover pasture
- high rainfall, permanent pasture system
- GrassGro used to interpret results

Rainfall: Hamilton 1979-1988



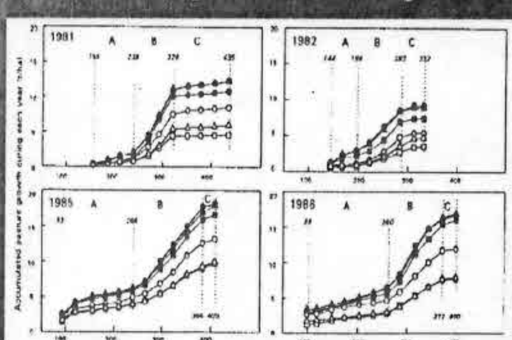
Rates of P (kg/ha/year) applied as single superphosphate at six levels

Year	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
1979	0.0	4.0	16.0	36.0	64.0	100.0
1980	0.0	4.0	16.0	36.0	64.0	100.0
1981	0.0	2.4	9.6	21.6	38.4	60.0
1982	0.0	1.6	6.4	14.4	25.6	40.0
1983	0.0	0.0	0.0	0.0	0.0	0.0
1984	4.0	8.2	13.9	21.1	29.8	40.0
1985-87	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.0	20.2	61.9	129.1	221.8	340.0

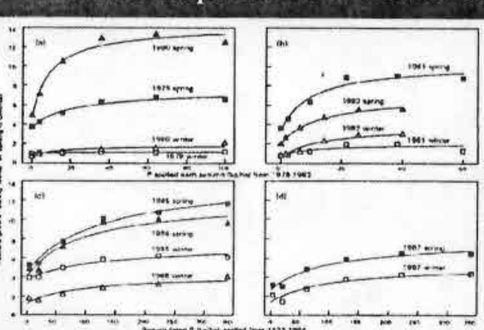
Stocking rate (sheep/ha) of treatments during the final year of the experiment

Grazing pressure	Level of fertiliser 1	2	3	4	5	6
Low	7.5	8.75	10.0	10.0	11.25	12.25
Medium	10.5	12.25	14.0	14.0	15.75	17.5
High	13.5	15.75	18.0	18.0	20.05	22.5
Sheep/plot	6	7	8	8	9	10

Cumulative production of pasture



Pasture response to P fertiliser

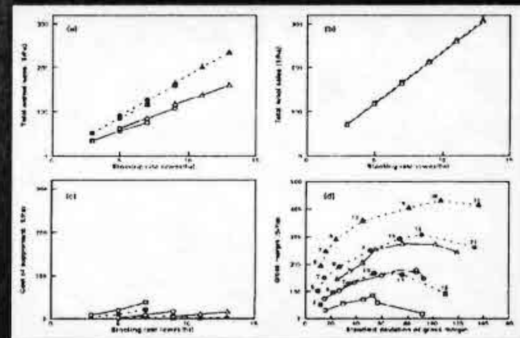


GrassGro analysis & assumptions

- **Fine wool Merino ewes**
- **3 soil P levels (fertility scalar, 0.5, 0.7, 0.9)**
- **7 stocking rates (5-21 ewes/ha)**
- **autumn or spring lambing**
- **pasture costs (15, 20, $30/ha)**
- **system analysed for period 1971-1995**

Extended experimental results over time and beyond experimental treatments

GrassGro simulations: 1971-1995

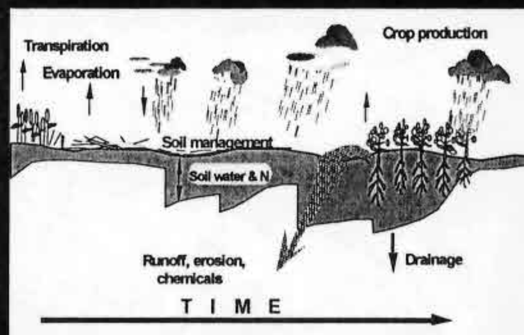


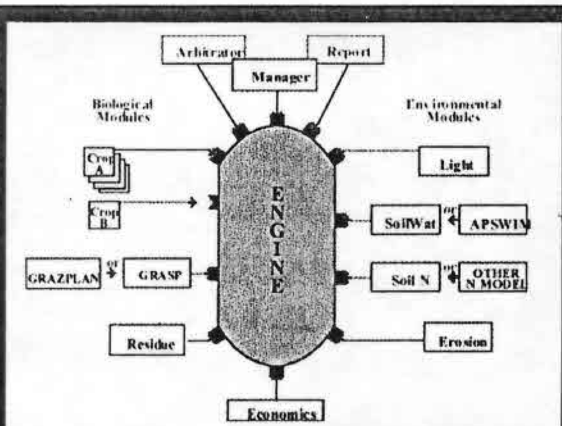
Some messages from Hamilton

- **High fertiliser *and* high stocking rates can be very profitable in this environment**
- **extra pasture production in spring from high P requires livestock management that can utilise the extra production, for example, spring lambing**
- **GrassGro simulations able to identify a profit - risk relationship**

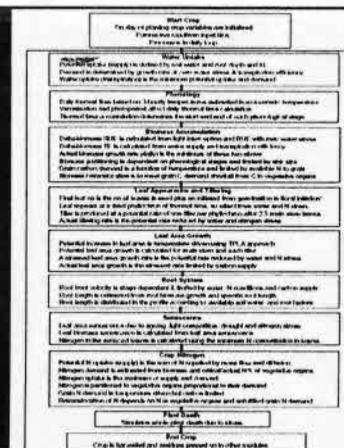
Cayley, et al. (1998) AJAR 49, 233-248

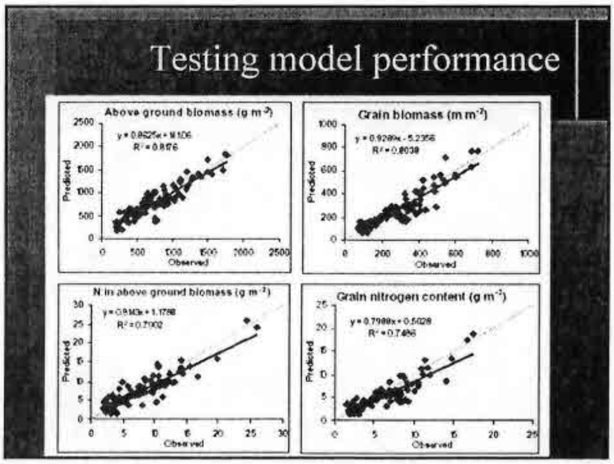
Schematic diagram of some of the processes simulated in APSIM

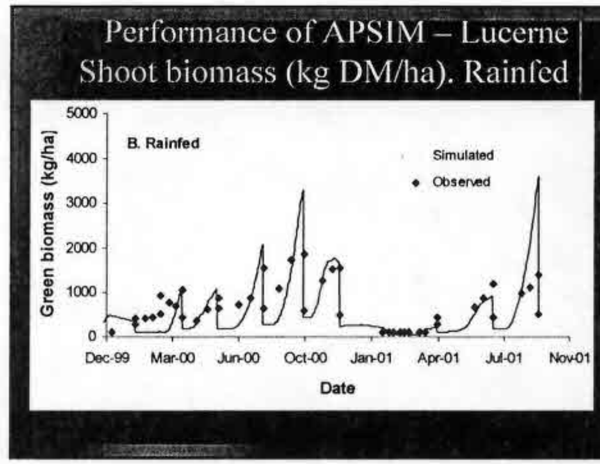


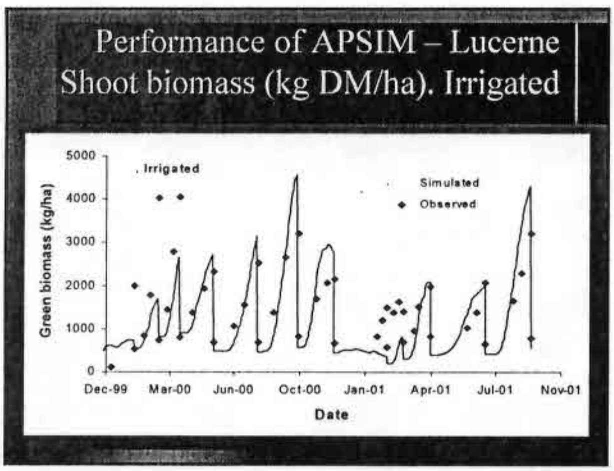


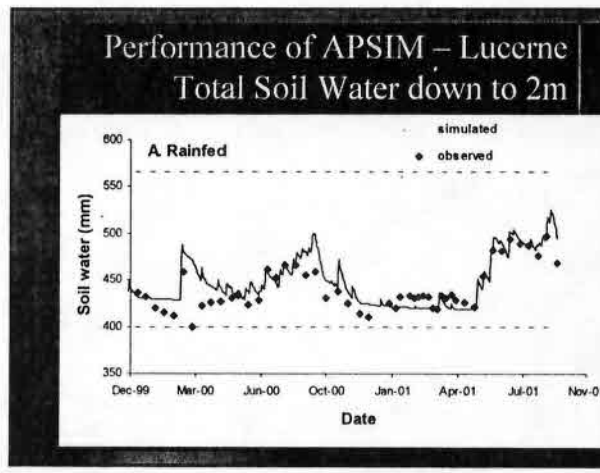
Processes simulated in the APSIM crop and pasture modules

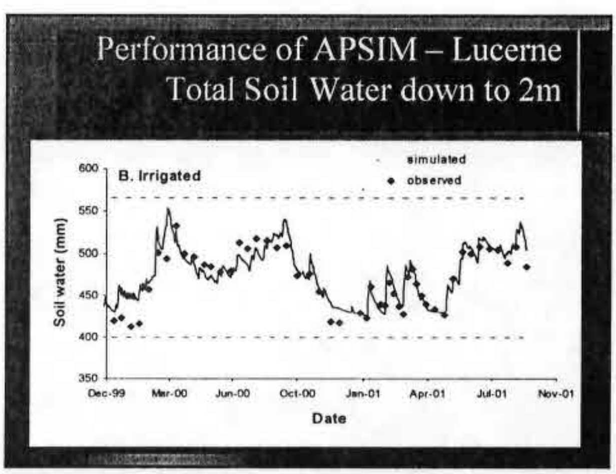






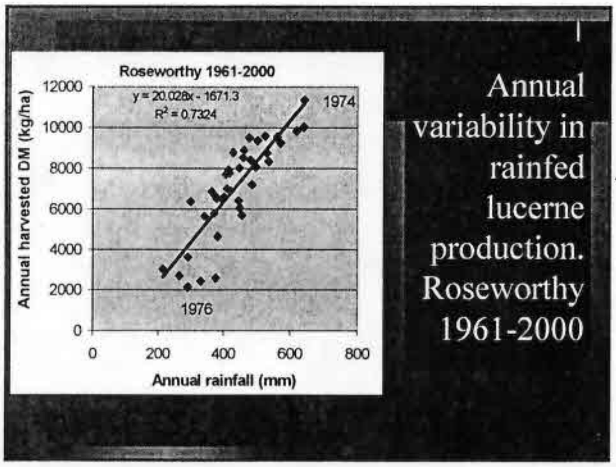


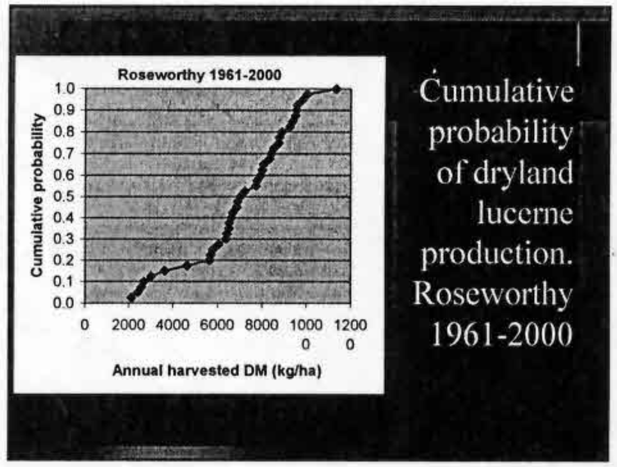


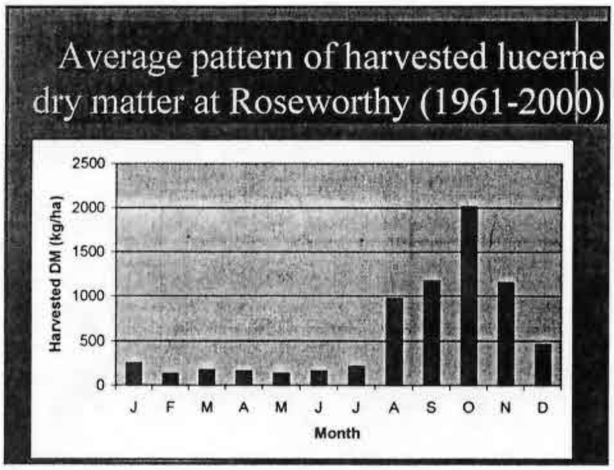


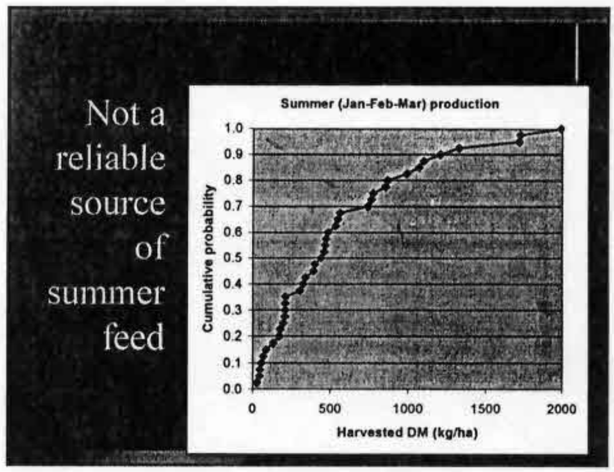
Summary of annual production

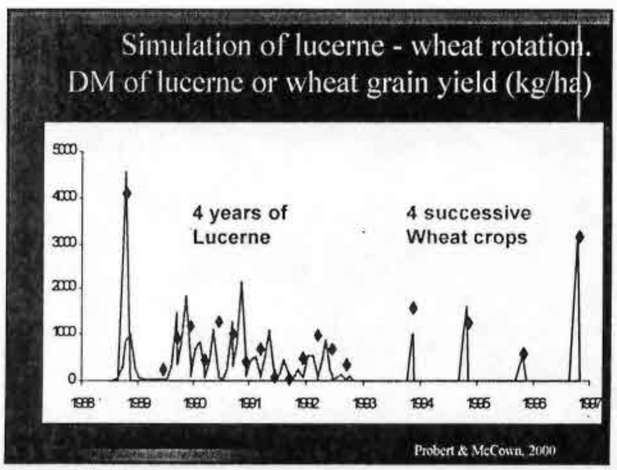
Year	Harvest number	Rainfed Observed	Rainfed Simulated	Irrigated Observed	Irrigated Simulated
2000	7	8.3	9.9	20.3	19.4
2001	5	3.2	5.0	10.1	10.7





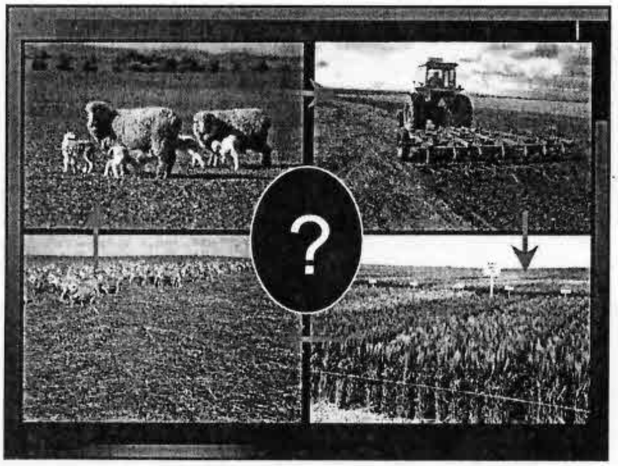


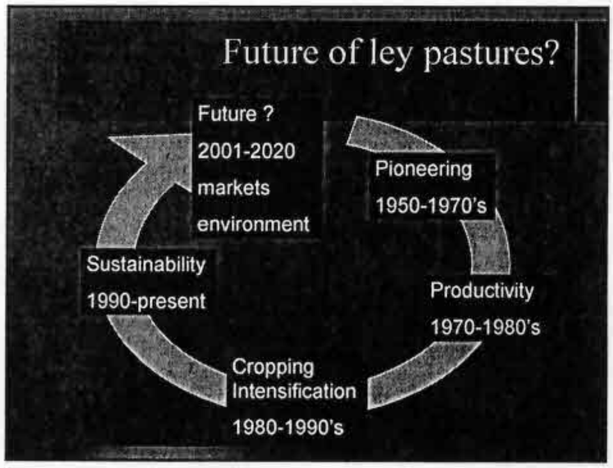




Example applications of APSIM

- **Predict productivity of crop - pasture rotations under variable climate**
- **Assess long-term impact of crop - pasture rotations on soil quality**
- **Compare rates of deep drainage under contrasting farming systems**
- **Conduct participatory research into farm management for farmers & researchers**





Conclusions

- **Rapid change in farming systems and role of pastures**
  - **new species meeting new requirements**
- **Shift in emphasis from *production* focus to a *profit and sustainability* focus**
  - **increasing complexity**
  - **increasing role for simulation modelling**
- **Pasture science integrated with Farming Systems Research has an important future role in addressing many current social and environmental issues**

Presentación oral (Power Point) a productores, ciudades de Curicó, Chillán, Temuco y Valdivia

The role of pasture legumes in sustaining productive and efficient cropping systems

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Universidad de Adelaida, Australia

El rol de praderas leguminosas en la sostenibilidad de la producción y eficiencia de los sistemas de cultivos

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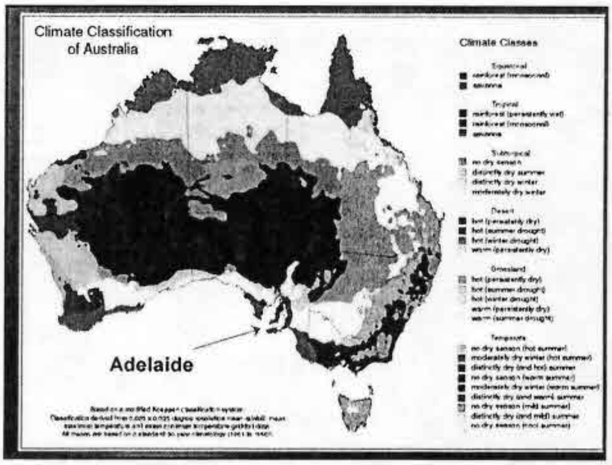
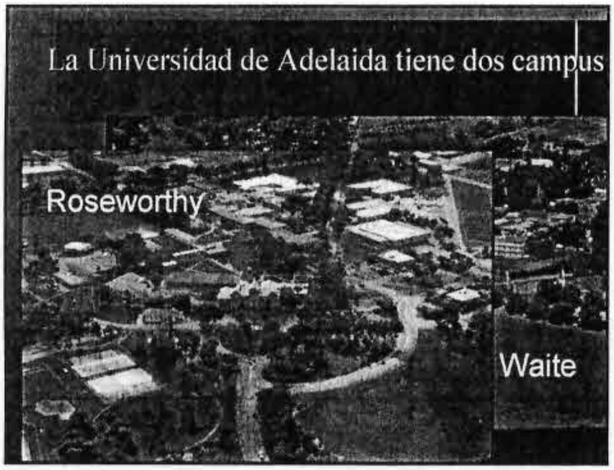




Presentación

- **Situación actual y cambios recientes**
  Current status and recent developments
- **Interacción entre praderas y cultivos**
  Interactions between pasture and crop
- **Producción animal a pastoreo**
  Animal production from grazed pastures
- **Futuro rol de praderas en los sistemas con cultivos**
  Future role of pastures in cropping systems

Praderas de leguminosas tradicionales

- anuales
- raices superficiales
- auto-regeneración
- aloja algunas enfermedades de cereales

Rol tradicional de praderas en los sistemas con cultivos

- Diversify income
  - livestock a… crop co… ditie…
- Maintain soil fe…
  - biologic…
  - maintenan… structure
- Sustain cr…
  - disease and wee…

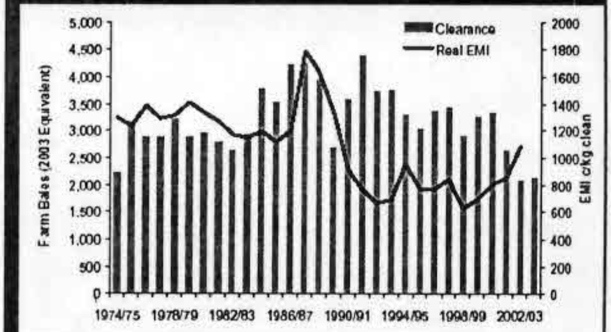
Traditional role under threat

New opportunities emerging

Tendencias de cambio

- Economic pressures
  - low profitability of wool enterprises compared to alternative break crops (pulses and oilseeds)
- Need to maximise crop productivity
  - low crop yield after some pastures
  - root diseases after some pastures
- Threats to sustainability
  - herbicide resistant weed populations
  - spread of dryland salinity

Precio histórico de lana (c/kg lana) 1974-2003



Praderas → Cultivos

Como las praderas influyen sobre los cultivos?

- nitrogen fixation, soil nitrate
- soil organic carbon
- soil structure
- cereal root disease management
- weed management
- pasture residues

Ciclo de Nitrógeno

- greater legume biomass, greater N fixed
- rule-of-thumb
  - 25 kg N fixed / tonne legume shoot DM
- however, if below-ground included
  - 40-50 kg N fixed / tonne legume DM
- effect of grazing on N cycling

Carbono orgánico en el suelo

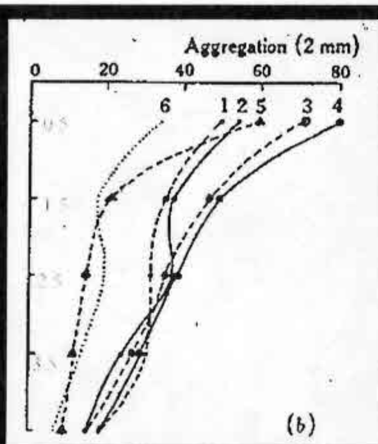
- pasture impact on SOC depends on productivity
  - legume-dominant pasture increases SOC
  - grass-dominant pasture may result in slow decline in SOC
- 3 Carbon input pathways from pasture
  - shoot residues
  - root residues
  - direct release of C from roots (rhizodeposition)

Estructura del suelo

- generally positive impact
  - little or no tillage in most pasture years
  - greater root biomass under pasture compared to crop
- grasses more beneficial than legumes
- livestock can have negative effect
  - trampling, surface soil compaction
  - powdering, wind erosion

Cambios en la estructura del suelo después de 2 años de pradera.

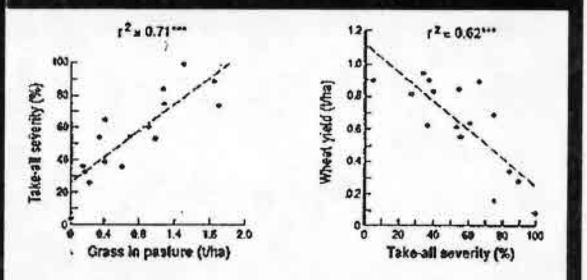
1. Phalaris –N
2. Phalaris +N
3. Ryegrass –N
4. Ryegrass +N
5. Subclover
6. Starting condition



Enfermedades de las raíces de cereales

- grass removal reduces some diseases
  - CCN
  - takeall
- other diseases hosted by legumes (medics)
  - rhizoctonia
  - root lesion nematode
- some leaf diseases may increase following grassy pasture

Gramíneas anuales hospedan enfermedades de raíces en trigo



MacNish & Nicholas (1987) A.J.A.R. 38, 1011.

Interrelations of grass content of pasture, take-all severity and yield of wheat following pasture in Western Australia.

Dinámica de semillas de malezas

- traditional management
  - take out monocots in pasture, dicots in cereal
- pastures often seen as a weak link in modern weed management systems
- herbicide resistant weeds
  - pastures provide range of options
  - grazing, hay or silage, spray-topping, winter cleaning, lucerne

Praderas Cultivos

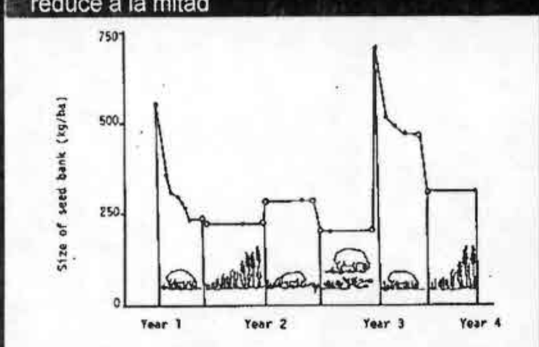
Como los cultivos afectan las praderas?

- rotation (non-pasture years)
- herbicide residues
- reduced tillage
- stubble retention
- nitrogen fertiliser

Rotación (Secuencia de cultivos)

- trend towards increasing cropping intensity
  - no seed production in crop years
  - seed bank reduced by approx. 50% each crop
- climatic variability and pasture growth
  - pastures sensitive to late breaks
  - seed production low in dry years
- combination of rotation and climate variability

Cada año que un cultivo se siembra, el banco de semillas de leguminosas se reduce a la mitad



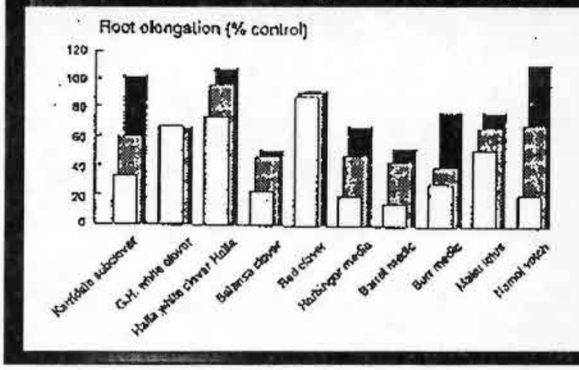
Reducir aradura

- trend towards minimum tillage or direct drilling
- greater reliance on chemical weed control
- effect on pasture legume seed bank
  - burr/pod burial by tillage may slow rate of seed softening, increasing legume persistence
  - burrs/pods on soil surface experience greater fluctuations in temperature and moisture which may promote seed softening

Residuos de cultivos

- trend towards retention of crop stubbles
- physical effects of stubbles
  - insulates temperature fluctuations
  - conserves surface soil moisture
- chemical effects of stubbles
  - leaching of allelochemicals toxic to legumes
- biological effects of stubbles
  - increased biological activity
  - fungal diseases

Extractos de paja de trigo reducen elongación de raíces en praderas de leguminosas – alelopatía.



Residuos de Herbicidas

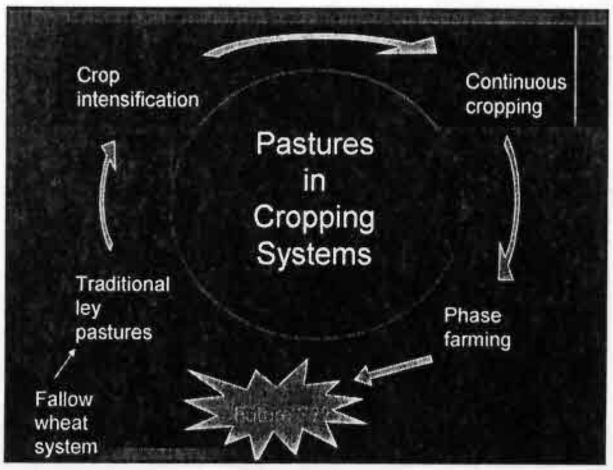
- improved in-crop weed control limits legume seed production in crop years
- increased use of SU's
  - highly residual on alkaline soils
  - medics highly sensitive
- spray-topping and broadleaf herbicide use in pasture year for control of crop weeds reduces vigour and seed production of pasture legumes

Fertilización con Nitrógeno

- increased use of nitrogenous fertilisers
- soil nitrate levels increasing
- pasture legumes reduce N fixation in presence of soil nitrate
  - soil nitrate at break of season can be high
- non-legumes have competitive advantage
  - increase in nitrophilous weeds (grasses, thistles)

Conclusiones

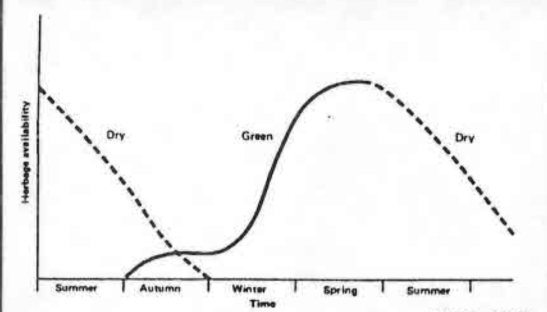
- interactions between pasture and crop are many, varied and complex
- pasture quality (legume content) has a strong bearing on whether a pasture will be beneficial or detrimental to a following crop
- many of the developments in modern cropping technology have had negative impacts on following pastures



Producción Animal a pastoreo en praderas anuales Mediterráneas

- Average pattern of herbage availability
- Length of growing season
- Feeding value of different pasture plants
- Relationships between intake and wool production
- Energy balance of grazing sheep on annual pastures

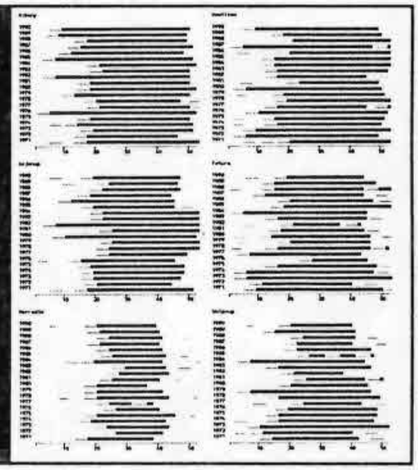
Disponibilidad de biomasa de praderas ade clima Mediterráneo.



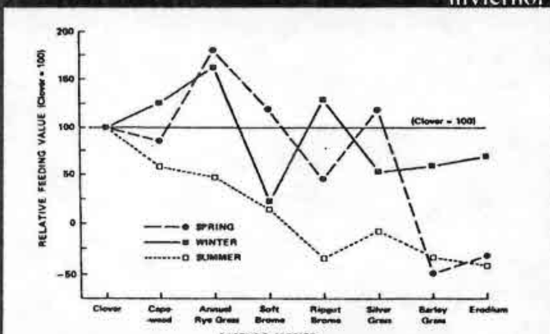
(Allden, 1980)

Growing season as defined by a simple soil water model

- Six locations.
- 1971-1990
- Thick lines represent growth.
- Thin lines represent false breaks.

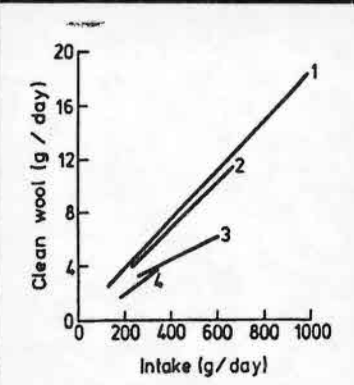


Valor nutritivo de distintas especies en relación a trébol subterráneo, en invierno, primavera e invierno

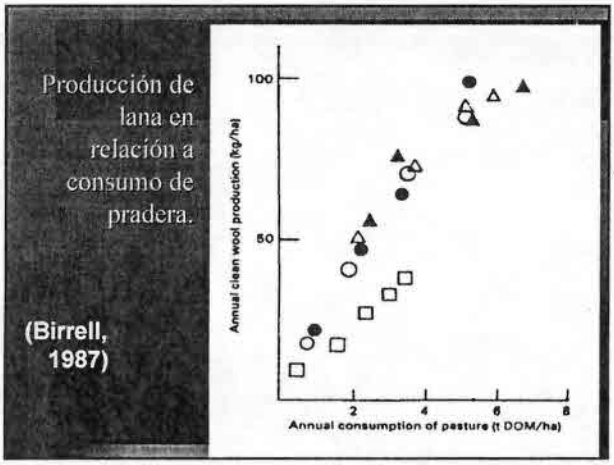


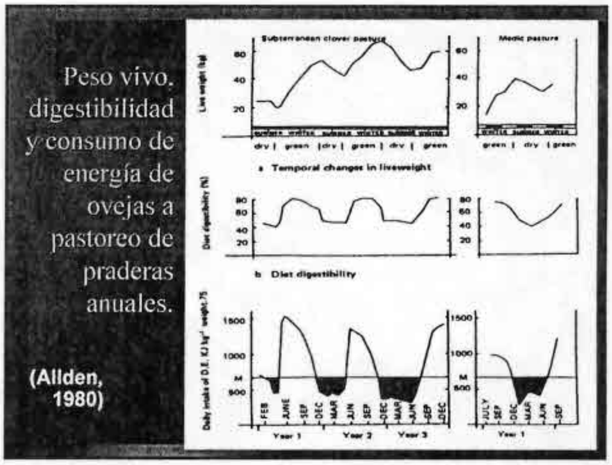
(Purser, 1980)

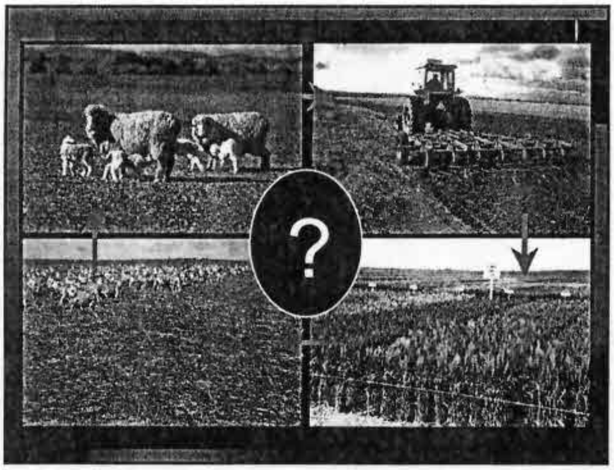
Relación entre crecimiento de lana y consumo de materia seca digestible



(Allden, 1979)







Conclusiones

- Rapid change in farming systems and role of pastures.
- Many complex interactions between pastures and crops: biological, economic, social.
- Key to high animal production is productive pastures and high utilisation of the pasture by the grazing animals.

Muchas gracias!

- Ministry of Agriculture
- Chile Society of Animal Production
- All of the pasture colleagues from Chile
- Daniel Troncoso
- Next time you visit Australia, be sure to drop in on Adelaide!

Documento en Acrobat Reader

Referencias a publicaciones de uso de modelos en agricultura

Publications

1. Scientific publication of the GRAZPLAN models

Donnelly, J.R., A.D. Moore, & M. Freer (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises. I. Overview of the GRAZPLAN project and a description of the MetAccess and LambAlive DSS. *Agricultural Systems* **54**, 57-76.

Freer, M., A.D. Moore, & J.R. Donnelly (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises. II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS. *Agricultural Systems* **54**, 77-126.

Moore, A.D., J.R. Donnelly & M. Freer (1997). GRAZPLAN: Decision support systems for Australian grazing enterprises. III. Pasture growth and soil moisture submodels and the GrassGro DSS. *Agricultural Systems* **55**, 535-582.

2. Publication of GRAZPLAN model validation

Bolger, T.P. and Moore, A.D. (1998) Extending the pasture model in the GRAZPLAN decision support system to evaluate management practices for maintaining improved pastures. *Final Report to the Meat and Livestock Authority. Project CS 230.* CSIRO Plant Industry, Canberra. 47 pp.

Clark, S.G., Donnelly, J.R. and Moore, A.D. (2000) The GrassGro decision support tool: its effectiveness in simulating pasture and animal production and value in determining research priorities. *Aust.J.Exp.Agric.* **40** pp.247-256.

Donnelly, J.R., Moore, A.D. and Freer, M. (1995) Calibrating, implementing and validating GRAZPLAN decision support systems for grazing enterprises throughout southern Australia. *Report to Australian Wool Research and Promotion Organisation-project CIC 38.* CSIRO Divison of Plant Industry, Canberra. 30 pp.

Moore A. D. (1996) Computer simulation of beef and sheep production in research and on-farm trials in south-western Western Australia. *Report to the Western Australian Department of Agriculture. Meat Research Corporation Project DAW.046,* CSIRO Plant Industry, Canberra. 36 pp.

Moore, A.D., Freer, M. and Donnelly, J.R. (1994) Calibration of the GRAZPLAN pasture growth model for ryegrass-subterranean clover pastures. Prime Lamb Program Systems Studies. *Interim Report to the Meat Research Corporation Project CS223.* CSIRO Plant Industry, Canberra. 9 pp.

Simpson, R.J., Salmon, L., Burbidge, G., Donnelly, J.R. and Moore, A.D. (2001) Farm systems for your environment. Proc. Grassland Soc. Vic. Annual Conf. Mt Gambier.

3. Industry applications of GrassGro

Topic	Location	Enterprise	Outcome	Publication
Sheep and cattle production				
Optimal heavy lamb production systems	SE Australia	Heavy prime lamb production	Comparison of economic risk associated with finishing lambs to heavy weights in different regions	Moore, Donnelly, Freer and Langford (1993). Report on Project CS149 to Meat Research Corporation. Moore, Donnelly and Freer 1995 Report on project CS223 to Meat Research Corporation
Simulation of lamb and sheep production trials on perennial pastures	Eleven locations in south-western WA	Steer fattening, beef cow herd, Merino wether wool flock, Merino ewe breeding flock	Defined seasonal patterns of pasture and sheep and cattle production in SW WA	Moore A.D. (1996) Report to Western Australian Dept Agriculture. Meat Research Corporation Project DAW.046
Evaluating backgrounding systems for beef herds on lucerne and annual grass pastures	Meningie, SA	Angus breeding herd	Higher cow stocking rates and retaining weaner calves as yearlings yielded higher gross margins	Salmon L. and Moore A.D.M. (1998) *Report to Australian Pastoral Research Trust.*
Time of lambing	Hamilton, south western VIC	Merino fine wool breeding flock	Demonstrated the benefit of spring lambing over autumn lambing	Cayley J.W.D., Hannah M.C., Kearney G.A. and Clark S.G. (1998) Aust.J.Agric.Res.49:233-48
Production of large lean lambs in breeding and finishing systems	SE Australia	Cross bred ewe flocks for breeding prime lambs and lamb finishing flocks	Production and economic risk of large lean lamb production in several regions of SE Australia	Salmon L., Freer M., Donnelly J.R. and Moore A.D. (1999). *Report to Rabo Australia Limited*
Setting achievable stocking rate targets	Bookham, southern tablelands, NSW	Wether fine wool flock	Assessing the optimum stocking rate in terms of economic returns, risk and supplements fed	Salmon L., Simpson R., Graham P. and Donnelly J.R. (2000) *Proceedings of the 41st Annual Conf. Grassland Society of Victoria*: 153
Optimising lambing date	Burraga, Central tablelands, NSW	Self replacing Merino breeding flock	Setting management priorities: optimizing the stocking rate was more profitable than changing the time of lambing in spring.	Behrendt K., Stefanski A. and Salmon E.M. (2000) *Proceedings of the 15th Annual Conf. Grassland Society of NSW:* 127.
Estimating production risk for a grazing lease	Tarcutta, SW slopes, NSW	Self replacing Merino breeding flock	Comparison of pasture supply, optimum stocking rate, lambing date and business risk on home property and a proposed grazing lease.	Salmon L., Simpson R., Burbidge G., Donnelly J.R. and Stefanski, A. (2000). *Proceedings of the 16th Annual Conf. Grassland Society of NSW:* 59.

Drought				
Drought feeding	Ballan, Southern central, VIC	Merino wether wool flock	Probability of the amount of supplement required over summer	Alcock, Watson, Donnelly, Simpson and Moore (1998). *Proc. 9th Aust. Agronomy Conf. pp 298-301.*
Grasshopper predation	Monaro, NSW	Wether wool flock	Quantify the effect of grasshoppers on pasture supply for livestock	Donnelly and Freer (1998) *Report to Bureau of Resource Sciences. 6 pp.*
Evaluating objective criteria for the definition of exceptional drought	Wellington, NSW; Binginbar, NSW	Merino wethers; merino ewe breeding flock	Monitor exceptional drought circumstances based on a shire-by-shire simulation of supplements fed for animal survival	Donnelly, J.R., Freer, M. and Moore, A.D. (1998) Agric Systems 57: 301-313
Environmental impacts				
Prediction of pasture seed supply for modeling of plague mice populations	Mallee, VIC	Annual pastures	Evaluation of seasonal variation in pasture seed mass as a component of mouse plague models	R.P. Pech, G.M. Hood, G.R. Singleton, L.Salmon, B.Forrester and P.R. Brown: Models for predicting plagues of house mice (*Mus domesticus*) in Australia Chapter 4 in : "Ecologically-based management of rodent pests" Eds G. Singleton, H. Leirs, Z. Zhang and L.Hinds (1999)
Dryland salinity study in four catchments	Wanilla, SA Lake Warden, WA Billabong, NSW Kamerooka, VIC	Merino breeding flocks, prime lamb production, steer fattening	Simulation of deep drainage under several grazed pasture systems for typical regional livestock enterprises	Stefanski A., Simpson R., Salmon L., and Moore A.D (1999-2000) National Land and Water Audit Report: Simulation of Pasture Systems (Wanilla, Lake Warden, Billabong, Kamerooka).
Animal production and emission of methane and nitrous oxide	Canberra, ACT; Glen Innes, NSW; Wagga Wagga, NSW; Wongan Hills, WA	Merino wethers	Simulation of emission of methane and urinary nitrogen over 20 years at three stocking rates on unimproved and improved pastures at four sites in the HRZ and WSZ	Freer, M. (1996) Report to Hassall and Associates Pty Ltd for Department of Primary Industry and Energy. 17 pp
Use of spatial data with GrassGro to provide estimates of annual net primary production at a farm scale on the northern tablelands of NSW	Armidale, NSW	Merino ewes on improved, semi-improved and native pastures; 20-year simulation	Demonstration of how satellite imagery can be interfaced with a DS tool to provide information for precision management of grazing systems	Hill, M.J., Donald, G.E., Vickery, P.J., Moore, A.D. and Donnelly, J.R. (1999) Aust. J. Exp. Agric. 39: 285-300
Teaching				
University of New England, Armidale, NSW			Enhancing student learning with complex Decision Support Systems	Scott, J.M., Daily H.G., Moore A.D., Salmon E.M., .Donnelly J.R, McCook R (2001) *Proceedings of the 10th Australian Agronomy Conference*, Hobart.

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GrassGro Quality Assurance Simulations

GrassGro Quality Assurance Simulations

The plant and animal models in GrassGro have been tested by running simulations at seven key locations. Comparisons of GrassGro simulations against trial data are to be published as model validations in scientific journals. This document describes the results of a second stage of testing, which consisted of running the simulations used for model validation over a longer period (1969-1998) with a standardized enterprise and management.

Locations used in GrassGro testing met most of the following criteria:

1. each location was the site of a published grazing experiment conducted over at least three years
2. chronological series of animal and pasture data from the published trial were available.
3. a soil description of the experimental site, preferably with measurements of physical properties was available
4. the principal pasture species at that site were parameterized for GrassGro
5. a weather locality using temperature data from the site was available.

At each location a self-replacing Merino ewe breeding enterprise grazed a pasture described in the published trial. Ewes lambed in late July. Lambs were weaned at 12 weeks old and sold at 8 months. Ewes were fed barley to maintain their live weight whenever their body condition fell below a threshold that varied with the time of year (Appendix 1). In order to test the effect of pasture availability and quality on lamb growth, the condition of weaned lambs fell to score 1.0 before supplementation commenced. Ewe and lamb live weight changes and the frequency and quantity of supplementation reflect the soil type and fertility, pasture species, stocking rate, time of lambing and feeding threshold at each site.

Table 1 summarizes the main features of the test simulation and Table 2 shows the soil inputs at each location. The GrassGro input files that were used in these tests are included in the Simulations directory on this CD and are available for you to run. All inputs for each simulation may be examined by opening the simulation file in GrassGro (see Viewing Simulation Inputs in the GrassGro User Manual).

Table 1. Stocking rate and pastures simulated at each site

Location	Mean annual rainfall for period simulated	Stocking Rate	Pasture composition		
	mm	*Ewes/ha*	*Species1*	*Species 2*	*Species 3*
Canberra, ACT	730	12	Phalaris	Sub clover-Seaton Park	Annual grass -early
Glen Innes, NSW	900	18	Phalaris	White clover	
Hamilton, VIC	700	12	Perennial ryegrass	Sub clover -Leura	
Kybybolite, SA	570	8	Annual grass-early	Sub clover -Seaton Park	
Mt Barker, WA	690	12	Cocksfoot	Sub clover -Seaton Park	Capeweed
Mt Barker, WA	690	12	Annual ryegrass	Sub clover -Seaton Park	Capeweed
Roseworthy, SA	440	6	Annual grass-early	Medic-Paraggio	
Temora, NSW	560	5	Lucerne-HR	Sub clover -Seaton Park	Annual grass-early

GrassGro is designed for generic application at sites across southern Australia. It is intended that simulations of any particular pasture species will reflect the phenotype of the species that is appropriate for the location in which it is growing. Consequently the performance of the models should be acceptable at the seven sites. At this stage of GrassGro's development, simulated pasture composition is expected to give, at least, plausible outcomes. Key plant and animal outputs are examined over the 30 years simulated at each site, for example pasture species composition, the distribution of flowering dates of each species, net primary productivity (NPP), pasture growth and quality, animal live weight and supplement intake. GrassGro's performance at each site is briefly described in the following pages.

Note:

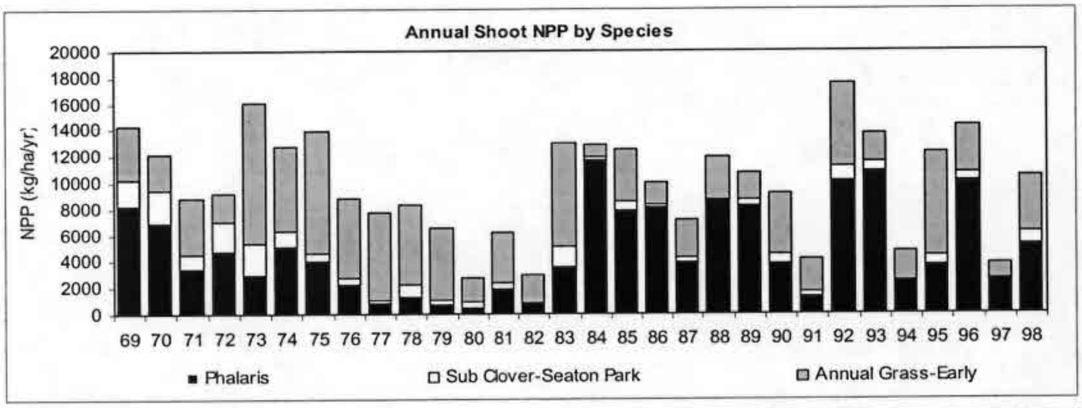
1. *The values presented for pasture growth rates and yields, supplementary feeding amounts etc are a consequence of both the behaviour of the GRAZPLAN simulation models and of the particular pasture species composition and management system to which they have been applied. In particular, different stocking rates or supplementary feeding policies – especially for lambs – would have produced different numerical results. When interpreting these results, the management system that was simulated must be kept in mind.*
2. *The available pasture shown in the graphs is the amount of herbage removed by cutting at ground level with a shearing handpiece. Typically 300-400 kg DM/ha remains when this method of cutting is used.*
3. *GrassGro assumes that animals are weighed without fasting.*

Table 2. Soil inputs for test simulations

Locality	Soil Type	Texture Class		Fertility	Cumul. Depth (mm)		Field Capacity		Wilting Point		Bulk Density		Sat. Hyd. Cond.		Soil
		Topsoil	Subsoil	**Scalar**	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	**Evap.**
				0-1	*mm*	*mm*	*% vol*	*% vol*	*% vol*	*% vol*	*g/cm³*	*g/cm³*	*mm/hr*	*mm/hr*	*mm/d^0.5*
Canberra, ACT	Dy3.42	SL	C	0.90	300	1000	31	38	9	28	1.17	1.45	30.00	3.00	3.5
Glen Innes, NSW	Ug5.15	C	C	0.80	250	1000	38	42	23	23	1.35	1.49	10.00	3.00	3.5
Hamilton, VIC	-	SiCL	C	0.80	250	1000	32	48	13	33	1.06	1.33	8.30	1.00	3.5
Kybybolite, SA	Dy5.43	-	-	0.80	200	1200	25	27	10	18	1.40	1.80	30.00	0.10	3.3
Mt Barker, WA	Dy2.2	LS	MC	0.90	350	1200	15	31	6	22	1.30	1.30	60.00	10.00	3.3
Roseworthy, SA	-	SL	C	0.80	200	800	28	34	17	22	1.30	1.30	4.40	3.00	3.5
Temora, NSW	Gn2.11	-	-	0.80	300	2000	40	36	21	21	1.00	1.20	300.00	100.00	3.3

Canberra, ACT (Ginninderra Experimental Station)

(a)



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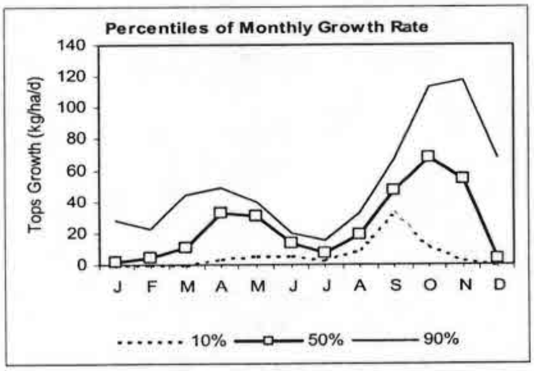

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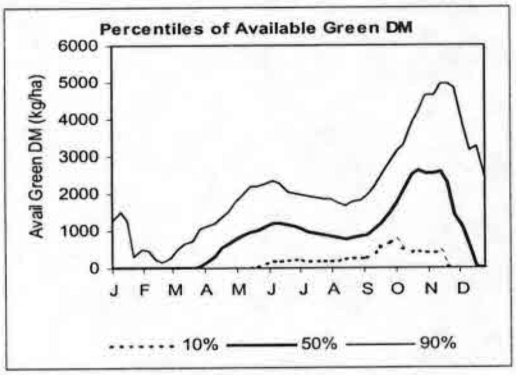

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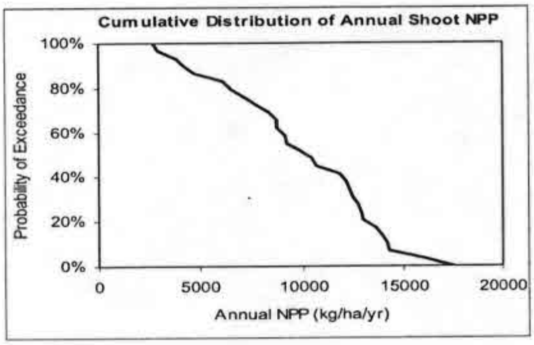

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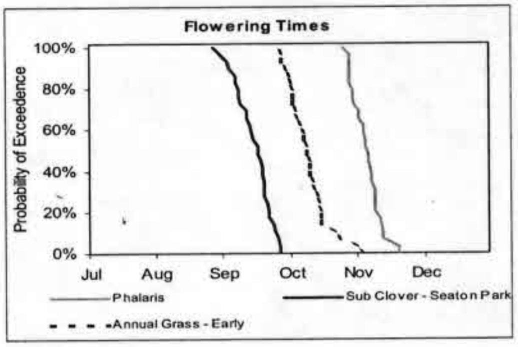

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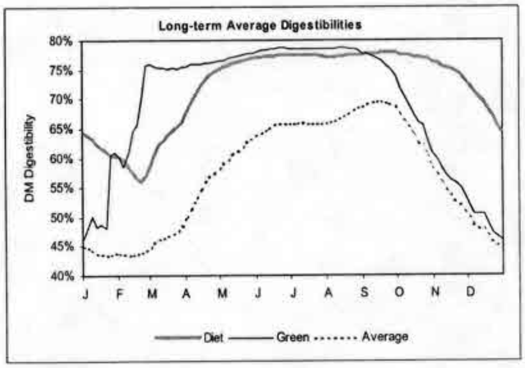


Pasture

Species composition

Mean pasture yield as net primary productivity (NPP) at Canberra was 10 t/ha and rarely exceeded 15 t/ha (graphs a and d). Each species persisted over 30 years (a). The average proportion of each species was: phalaris 49%, subterranean clover 8% and early flowering annual grass 43%.

Growth

In half the years pasture growth rate exceeded 32 kg DM/ha/day at the peak of autumn, 8 kg DM/ha/day in July and 68 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from early April in half of all years; green pasture was present until late November in 90% of years and until mid-December in 50% of years. In half the years, 2.5 t/ha or more of green pasture was available at the peak of spring (c). In 10% of years, 1.5t/ha or more of green pasture was available in January and green pasture was present in low amounts during February and March. However in more than 50% of years, no green pasture was available in January-March.

Quality

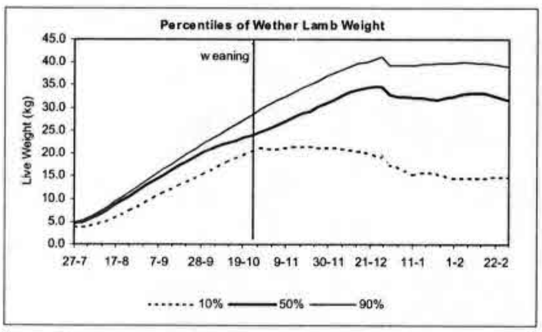
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). On average, the digestibility of the whole pasture exceeded 50% from early April until early December. The digestibility of green herbage declined from early September and fell below 70% in the first week of October. Animals selected a diet that had an average digestibility of greater than 70% until mid-December.

Livestock

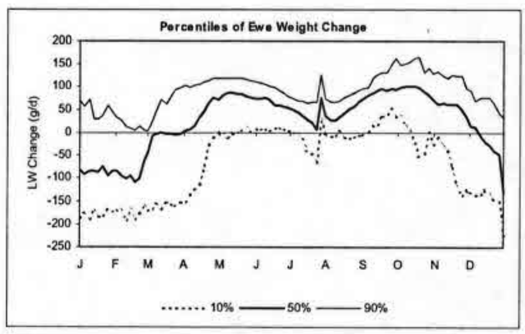
In half the years, the pre-weaning growth rate of wether lambs was at least 221g/head/day, (23.5 kg live weight at weaning) (g). In most years weaners continued to gain weight until mid-December. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined; median lamb live weight was maintained above 30 kg from early January until sale in late February. In about 10% of years, lambs failed to gain weight after weaning.

In half the years, ewes lost weight between late December and March (h). Ewe live weight gains (less fleece and conceptus) declined in late pregnancy and increased in spring. Supplementary feeding of ewes was required at times ranging from January to mid-September but it was most likely to be needed during February-March and in late pregnancy (j). Some supplementation of ewes was required in 20 of the 30 years simulated (i) but in half the years the amount fed was less than 12 kg/ewe/year. Most feeding coincided with droughts in the early 1980s and 1991,1994 and 1997 (a,i).

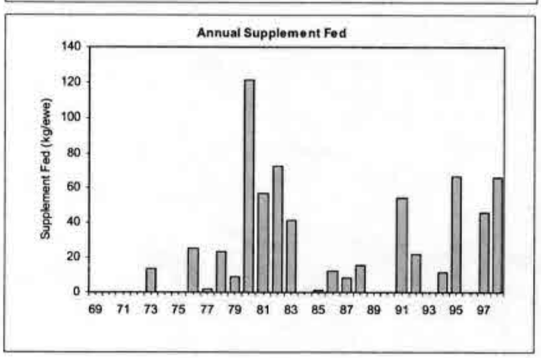
(g)



(h)



(i)



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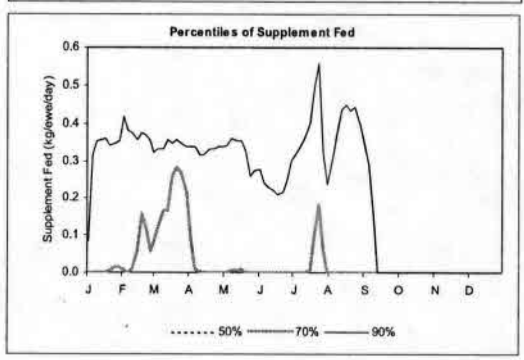
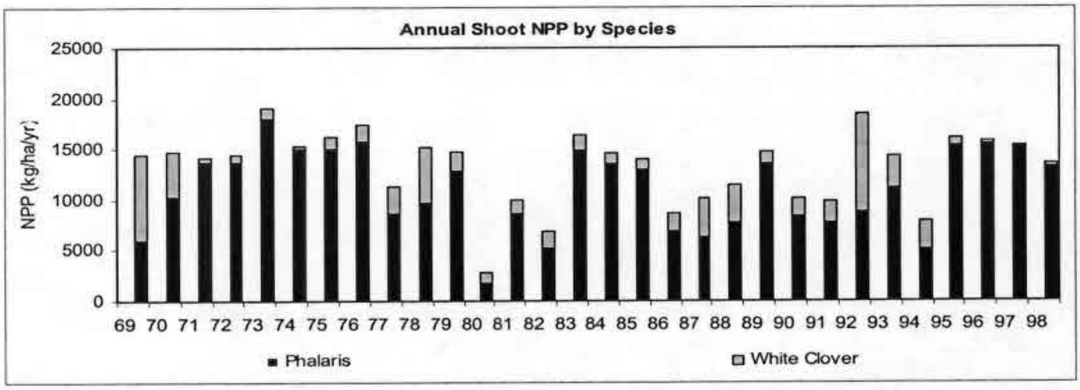


Glen Innes, NSW

(a)



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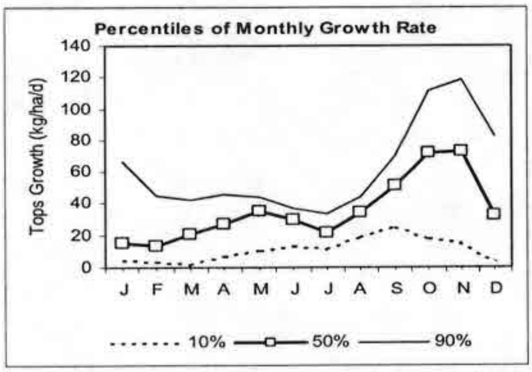
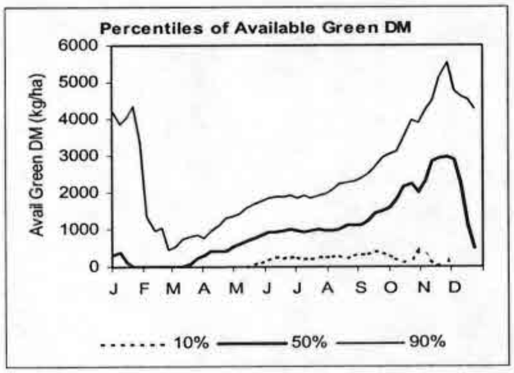


(c)



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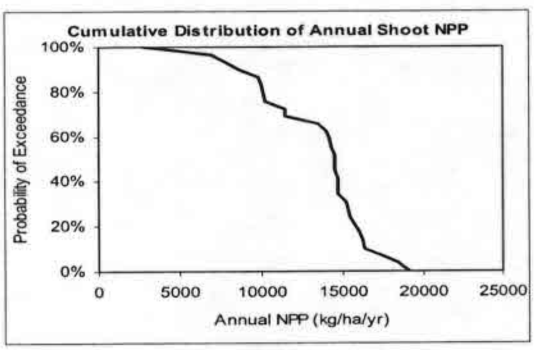

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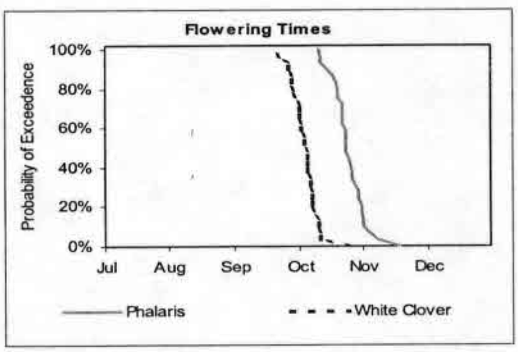
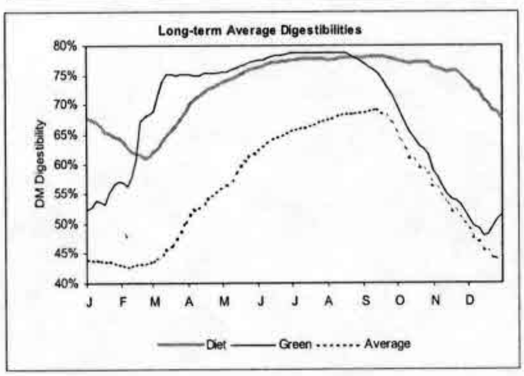


(f)



Pasture

Species composition

Mean pasture yield as NPP at Glen Innes was 13 t/ha and rarely exceeded 16 t/ha (graphs a and d). White clover persisted in a phalaris-dominant pasture over 30 years (a). The average proportion of each species was: phalaris 83% and white clover 13%.

Growth

In half the years pasture growth rate exceeded 35 kg DM/ha/day in May, 21 kg DM/ha/day in July and 72 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from mid-March in half of all years; green pasture was present until December in 90% of years and until late January in 50% of years. In half the years, 2.5 t/ha or more of green pasture was available at the peak of spring (c). The availability of green pasture over spring and summer was highly variable. In the poorest 10% of years less than 500 kg/ha green pasture was available in spring, while in the wettest 10% of summers there was over 4000kg/ha of green pasture available at the end of January.

Quality

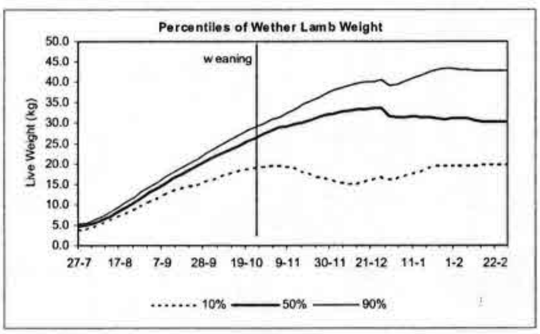
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). On average, the digestibility of the whole pasture exceeded 50% from late March to late November. The digestibility of green herbage declined from August and fell below 70% in late September. Animals selected a diet that had an average digestibility of greater than 70% from April until late December.

Livestock

In half the years, the pre-weaning growth rate of wether lambs was at least 245 g/head/day (25.4 kg live weight at weaning) (g). In most years weaners continued to gain weight until late December. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined and gain ceased. Median lamb live weight was maintained above 30 kg from early January until sale in late February.

In half the years, ewes lost weight between late December and March (h). Ewe live weight gains (less fleece and conceptus) declined in late pregnancy and increased slightly in spring. Supplementary feeding of ewes was required at different times of year ranging from January to mid-September but it was most likely to be needed during late February to March (j). Some supplementation of ewes was required in 18 of the 30 years simulated (i) but in half the years the amount fed was less than 20 kg/ewe/year. Most feeding coincided with drought in the early 1980s, poor seasons in 1986, 1991-92 (a) and late breaks in 1971 and 1998 (not shown).

(g)



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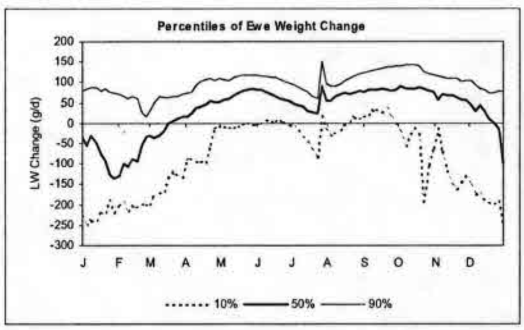
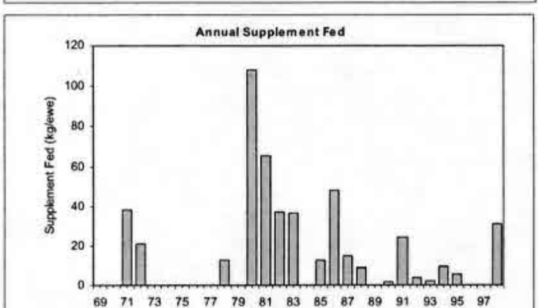
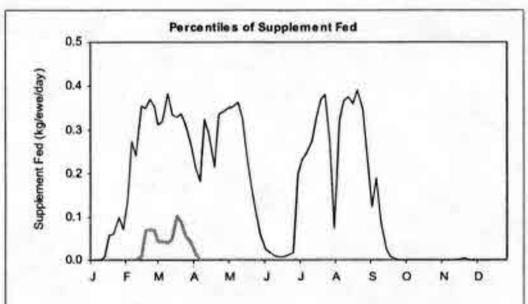


(i)

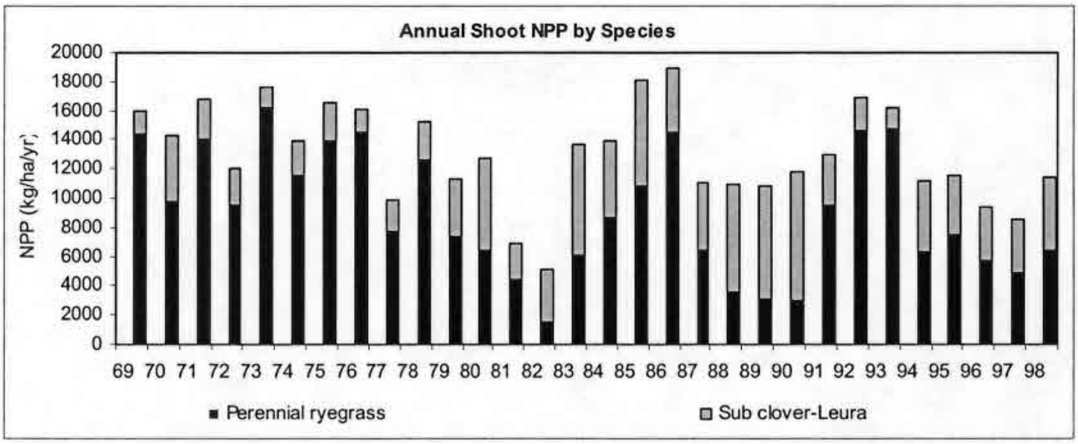


(j)

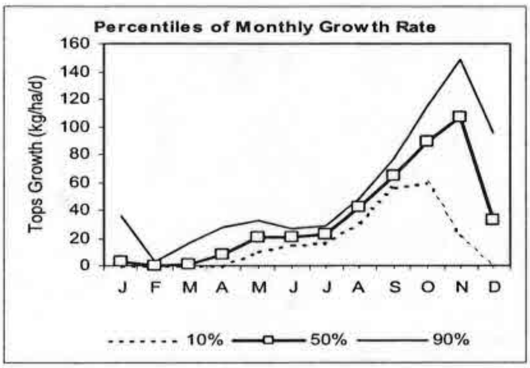


Hamilton, VIC

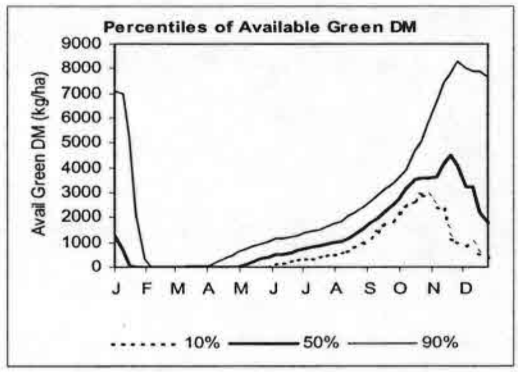
(a)



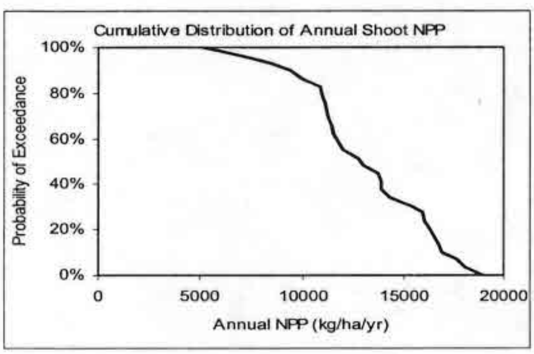
(b)



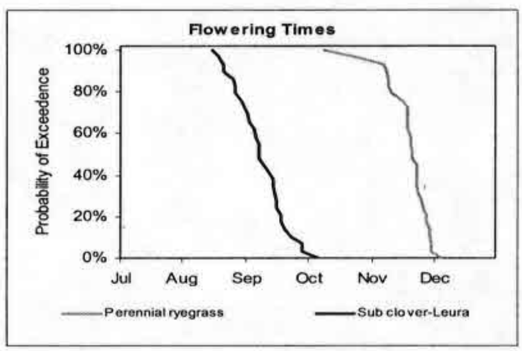
(c)



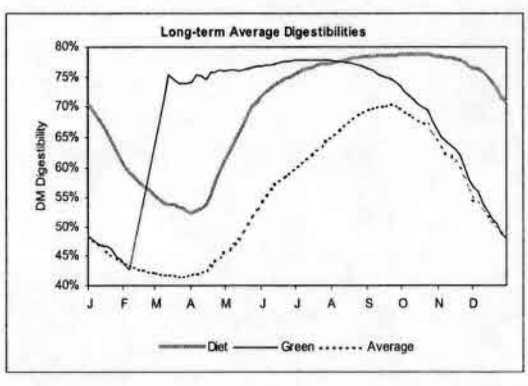
(d)



(e)



(f)



Pasture

Species composition

Mean pasture yield as NPP at Hamilton was 13 t/ha and rarely exceeded 17 t/ha (graphs a and d). Subterranean clover persisted in a perennial ryegrass-dominant pasture over the 30 years simulated (a). The average proportion of each species was: perennial ryegrass 69% and subterranean clover 31%.

Growth

In half the years pasture growth rate exceeded 21 kg DM/ha/day in autumn, 22 kg DM/ha/day in July and 106 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from early May in half of all years. In half the years, 4.4 t/ha or more of green pasture was available at the peak of spring (c). Green pasture was present until mid-December in 90% of years and until mid-January in 50% of years. In half of all years, there was 1000 kg/ha or more of green pasture available at the end of December.

Quality

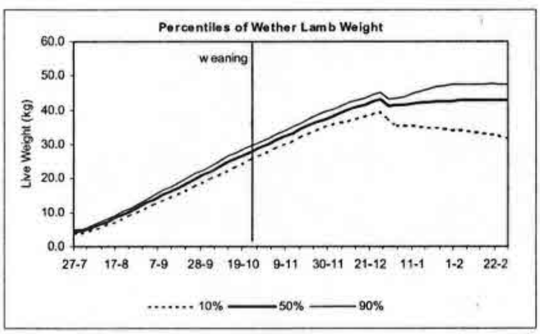
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). On average, the digestibility of the whole pasture exceeded 50% from mid May to late December. The digestibility of green herbage declined from August and fell below 70% in late October. Animals selected a diet that had an average digestibility of greater than 70% from May until the end of December.

Livestock

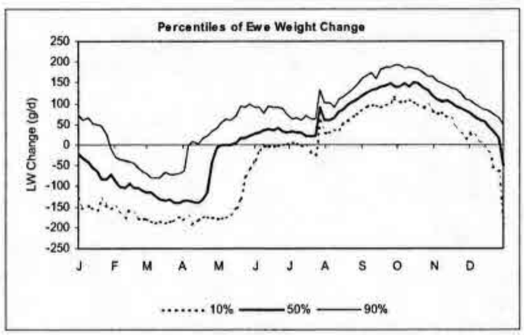
In half the years, the pre-weaning growth rate of wether lambs was at least 265g/head/day (26.7 kg live weight at weaning) (g). In most years weaners continued to gain weight until the end of December. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined; median lamb live weight was maintained above 42 kg from early January until sale in late February.

In half the years, ewes lost weight between the end of December and May (h). Ewe live weight gains (less fleece and conceptus) declined in late pregnancy and increased in spring. Supplementary feeding of ewes was generally restricted to the period from late March to July (j). Some supplementation of ewes was required in 16 of the 30 years simulated (i) but in 70% of years the amount fed was less than 7 kg/ewe/year. Most feeding coincided with droughts in the early 1980s and late 1990s and poor seasons in 1977, the late 1980s and 1990s (a,i).

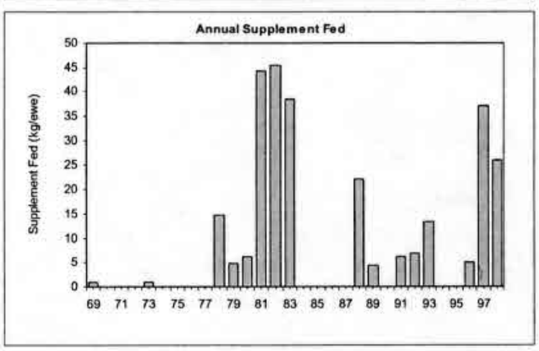
(g)



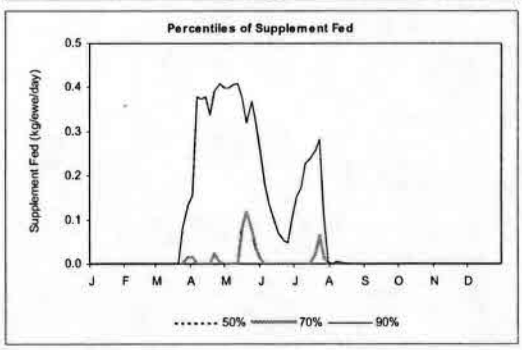
(h)



(i)



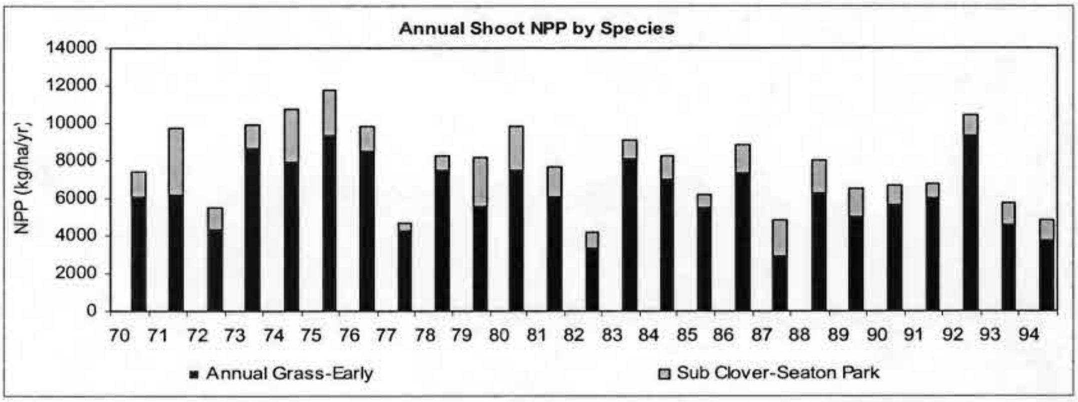
(j)



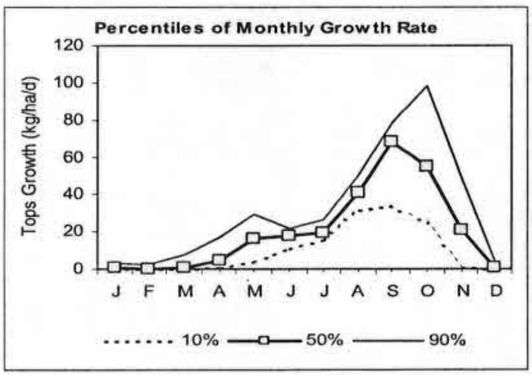
Kybybolite, SA

The length of this simulation was restricted to the years 1970-94 by the availability of weather data.

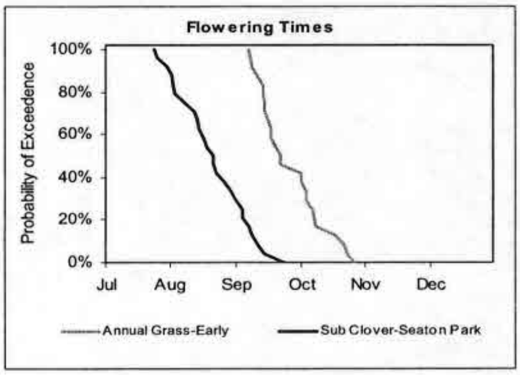
(a)



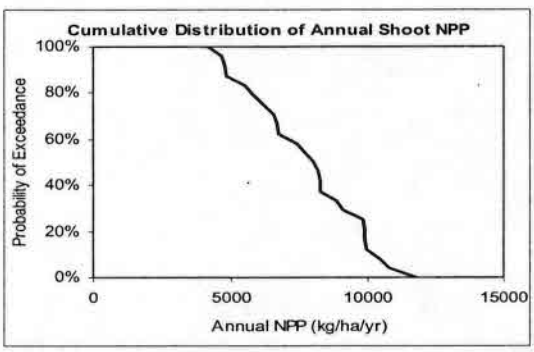
(b)



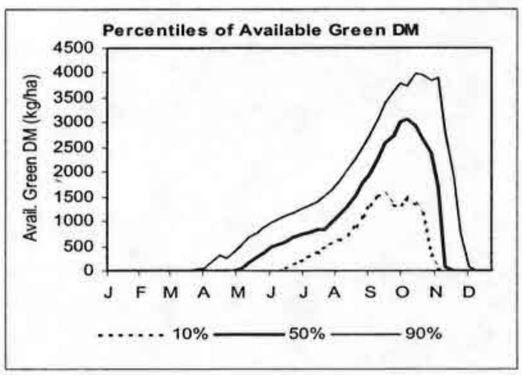
(c)



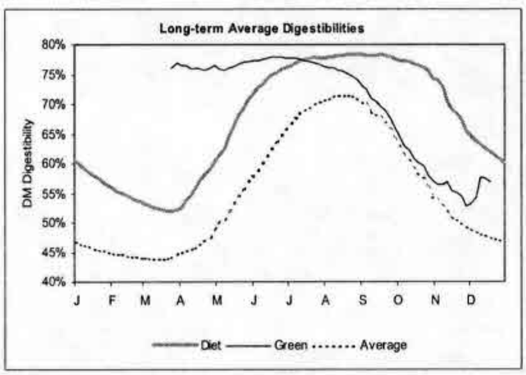
(d)



(e)



(f)



Pasture

Species composition
Mean pasture yield as NPP at Kybybolite was 8t/ha and rarely exceeded 10 t/ha (graphs a and d). Annual grass and subterranean clover persisted for the 25 years simulated (a). The average proportion of each species was: early-flowering annual grass 81% and subterranean clover 19%.

Growth
In half the years pasture growth rate exceeded 16 kg DM/ha/day in May, 19 kg DM/ha/day in July and 68 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from early May in half of all years; green pasture was present until the beginning of November in 90% of years and until mid-November in 50% of years. In half the years, 3.0 t/ha or more of green pasture was available at the peak of spring (c).

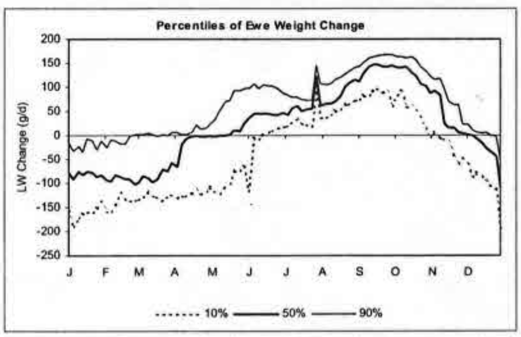
Quality
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). The average digestibility of the whole pasture exceeded 50% from May-mid November. The digestibility of green herbage declined from late July and fell below 70% in mid September. Animals selected a diet that had an average digestibility of greater than 70% until November.

Livestock

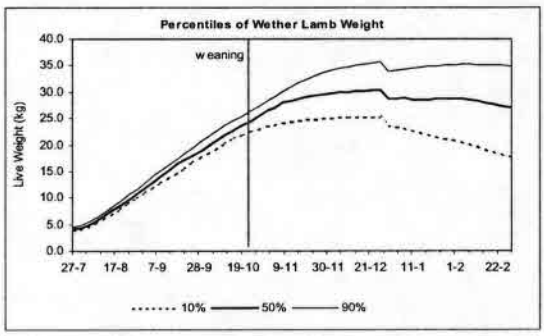
In half the years, the pre-weaning growth rate of wether lambs was at least 232g/head/day (23.7 kg live weight at weaning) (g). In most years weaners continued to gain weight until mid-December. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined; median lamb live weight was maintained above 27 kg until sale in late February.

In half the years, ewes lost weight between mid-December and mid-April (h). Supplementary feeding of ewes was generally restricted to the period from February to July but was most likely to be required during late March to mid-May (j). Supplements were fed to the ewes in all but 3 of the 25 years simulated; in half the years the amount fed was less than 21 kg/ewe/year. Most feeding coincided with severe droughts in 1977, 1982, 1993-94 and late breaks of season in 1987 and 1990 and 1991(a,i).

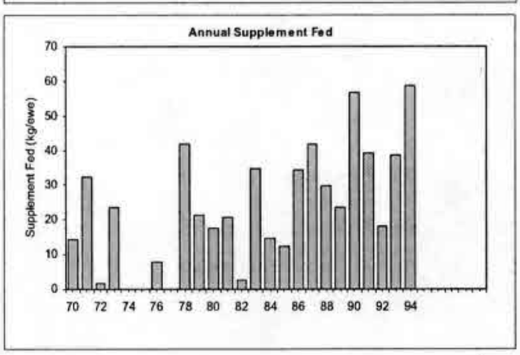
(g)



(h)



(i)



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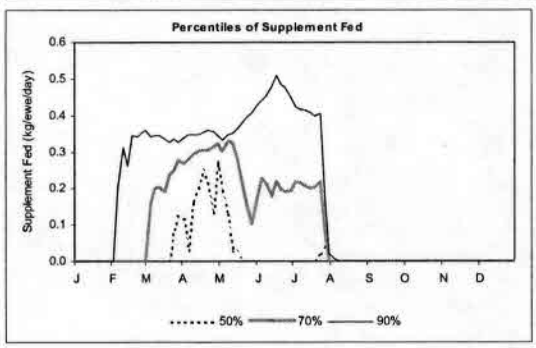
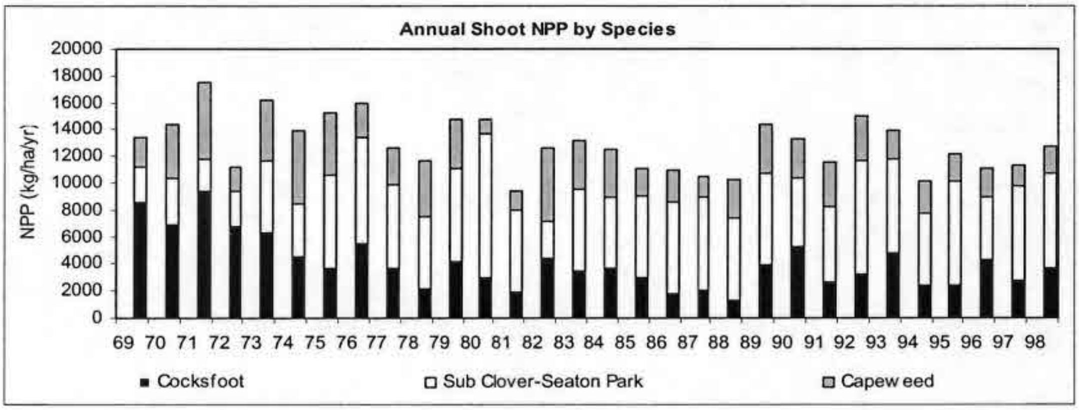
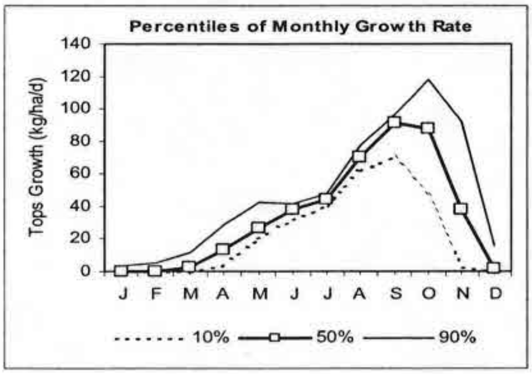


Mount Barker, WA (Perennial Pasture)

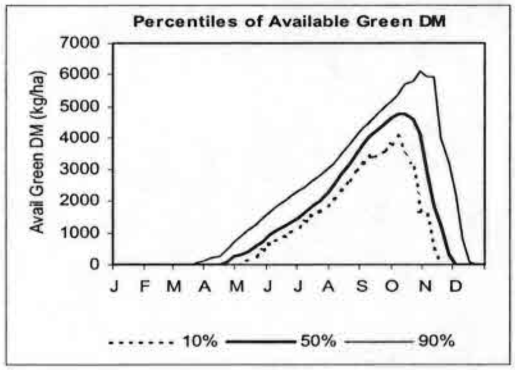
(a)



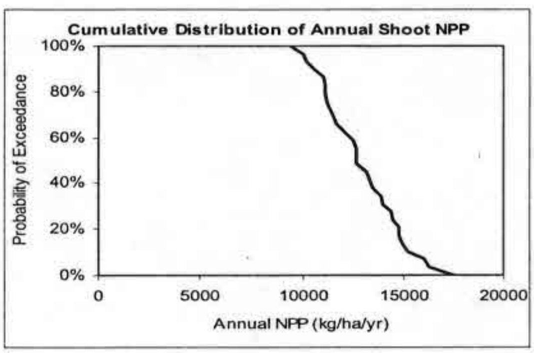
(b)



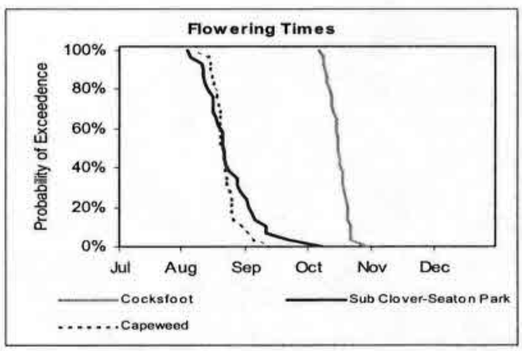
(c)



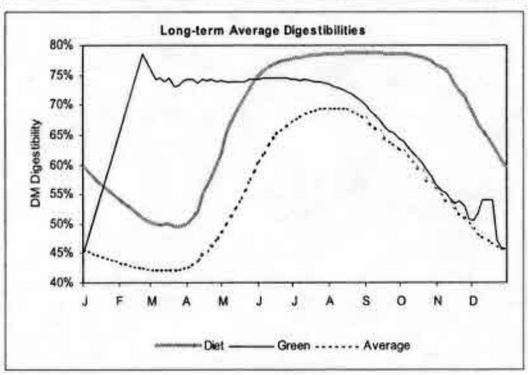
(d)



(e)



(f)



Pasture

Species composition

Mean yield as NPP for a perennial-based pasture at Mount Barker was 13t/ha and rarely exceeded 15 t/ha (graphs a and d). Each of the three species persisted over 30 years (a). The average proportion of each species was: cocksfoot 31%, subterranean clover 45% and capeweed 23%.

Growth

Pasture growth reflected the high soil fertility assumed at this site and the mild winter temperatures. In half the years pasture growth rate exceeded 27 kg DM/ha/day in May, 48 kg DM/ha/day in July and 91kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from late April in half of all years; green pasture was present until mid-November in 90% of years and until the end of November in 50% of years. In half the years, 4.8 t/ha or more of green pasture was available at the peak of spring (c).

Quality

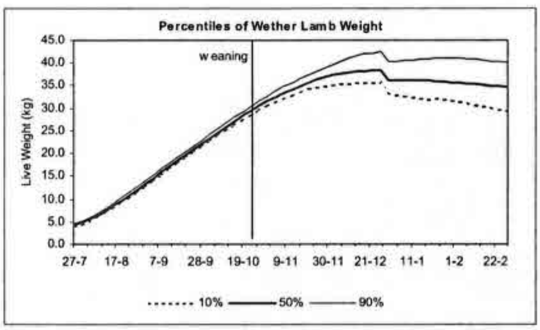
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). The average digestibility of the whole pasture exceeded 50% from May-December. The digestibility of green herbage declined from August and fell below 70% in early September. Animals selected a diet that had an average digestibility of greater than 70% until late November.

Livestock

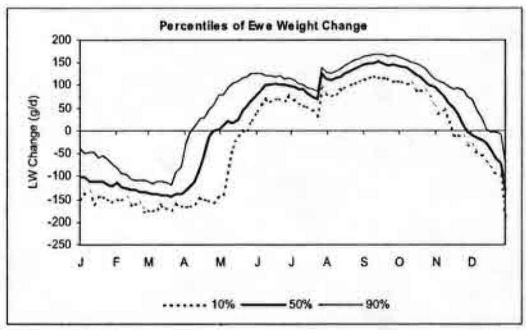
In half the years, the pre-weaning growth rate of wether lambs was at least 282 g/head/day (28.4 kg live weight at weaning) (g). This growth reflected the high (but realistic) legume content of the pasture. In most years weaners continued to gain weight until December. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined; median lamb live weight was maintained above 34 kg until sale in late February. In the worst 10% of years, lambs weighed less than 29 kg at sale.

In half the years, ewes lost weight between December and May (h). Supplementary feeding of ewes was generally restricted to the period from mid-March to the end of May (j). Some supplementation of ewes was required in 19 of the 30 years simulated (i) but in 70% of years the amount fed was less than 8 kg/ewe/year. Most feeding coincided with poor seasons in 1972, 1978, 1981, 1985-88, 1994-97 (a,i).

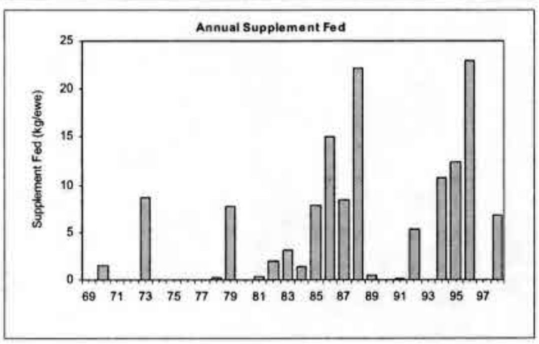
(g)



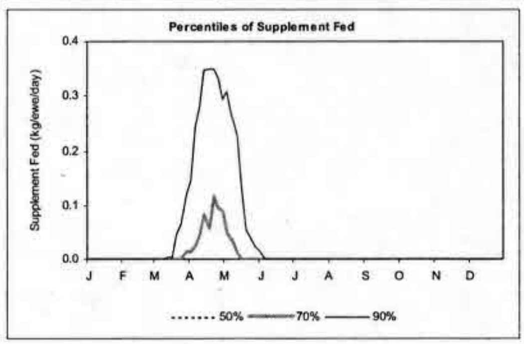
(h)



(i)

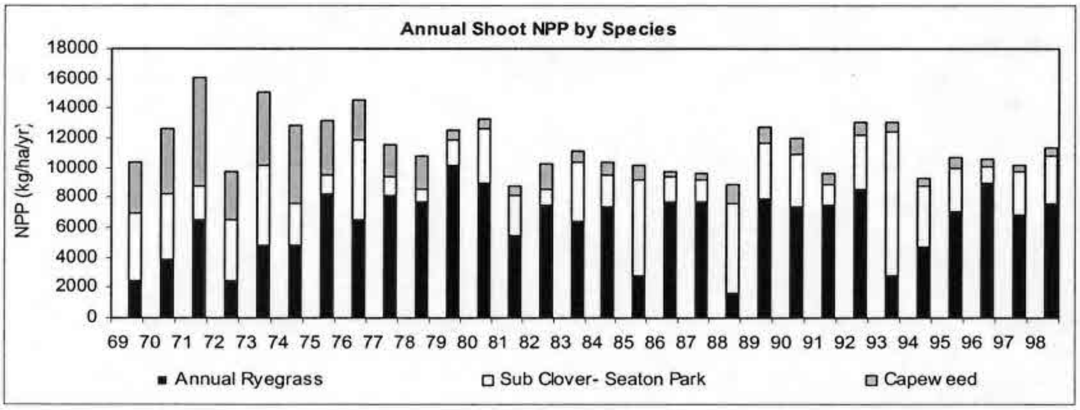


(j)

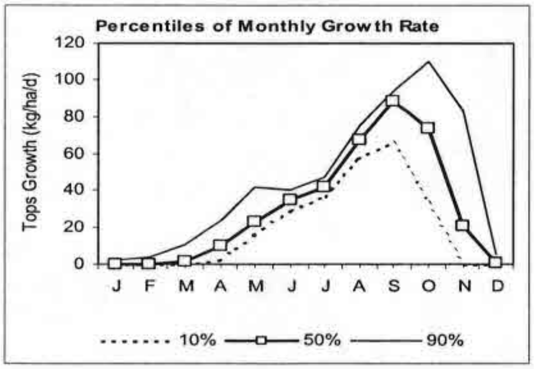


Mount Barker, WA (Annual Pasture)

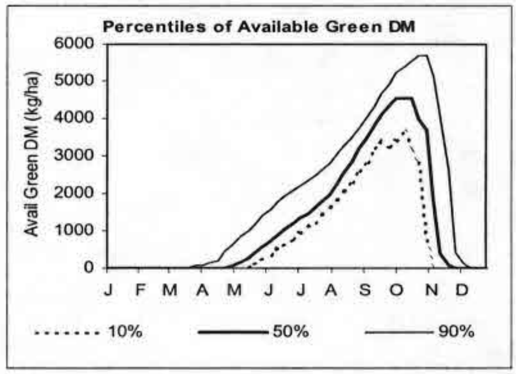
(a)



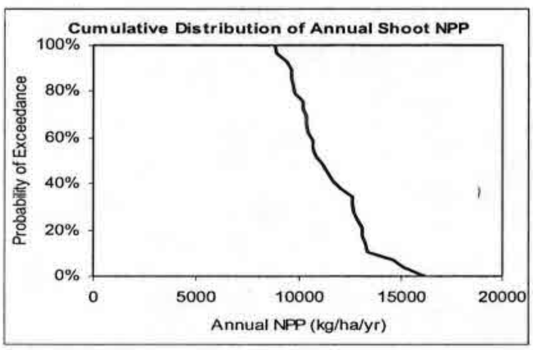
(b)



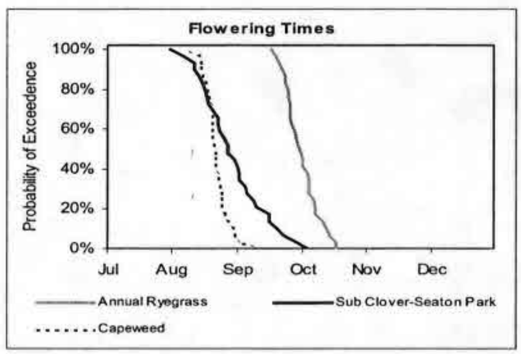
(c)



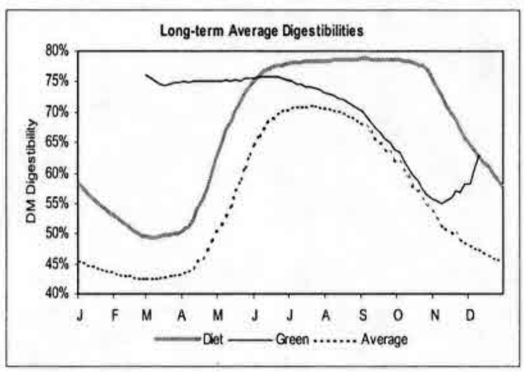
(d)



(e)



(f)



Pasture

Species composition

Mean yield as NPP of an annual pasture at Mount Barker was 11 t/ha and rarely exceeded 13 t/ha (graphs a and d). Each of the three species persisted for the 30 years simulated (a). While the amounts of annual ryegrass and subterranean clover were very variable, the amount of capeweed steadily declined. The average proportion of each species was: annual ryegrass 55%, subterranean clover 29% and capeweed 16%.

Growth

Pasture growth reflected the high soil fertility assumed at this site and the mild winter temperatures. In half the years pasture growth rate exceeded 23 kg DM/ha/day in May, 42 kg DM/ha/day in July and 89 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from early May in half of all years; green pasture was present until early November in 90% of years and until mid-November in 50% of years. In half the years, 4.5 t/ha or more of green pasture was available at the peak of spring (c).

Quality

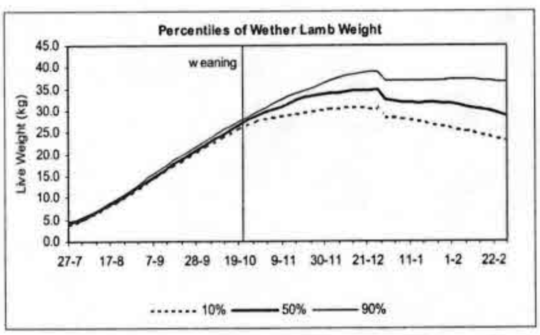
The digestibility of the annual pasture declined earlier and more rapidly than the perennial pasture at Mount Barker (e and f). The average digestibility of the whole pasture exceeded 50% from May-mid November. The digestibility of green herbage declined from June and fell below 70% in early September. Animals selected a diet that had an average digestibility of greater than 70% until mid November, which was nearly 2 weeks earlier than the perennial pasture.

Livestock

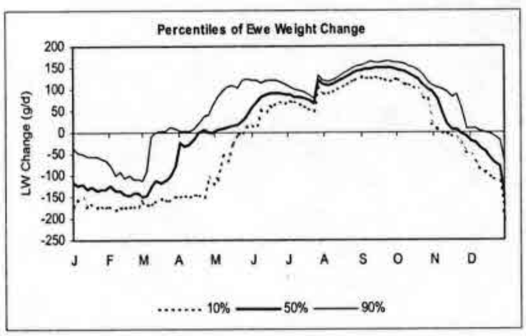
In half the years, the pre-weaning growth rate of wether lambs was at least 267g/head/day (26.9 kg live weight at weaning) (g). In most years weaners continued to gain weight until late November. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined; median lamb live weight declined over summer to 28kg in late February, 6 kg less than the equivalent sale weight on the perennial pasture.

On the annual pasture, ewes lost weight between mid-November and May in 50% of years (h). Supplementary feeding was mainly restricted to the period from March to mid-June (j). Some supplementation of ewes was required in 26 of the 30 years simulated (i). In 70% of years the amount fed was less than 19 kg/ewe/year; this was more than for the perennial-based pasture because of lower pasture quantity, quality and legume content in the simulated annual pasture.

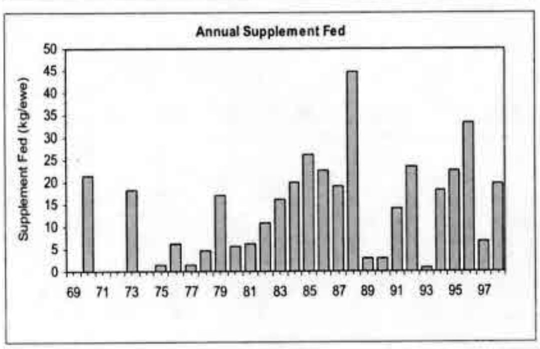
(g)



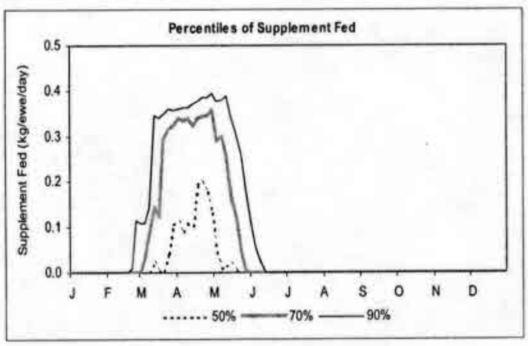
(h)



(i)

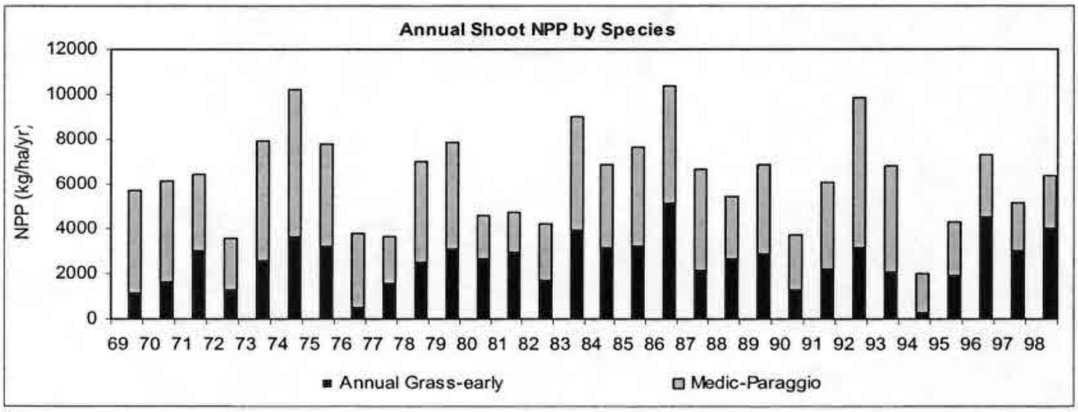


(j)

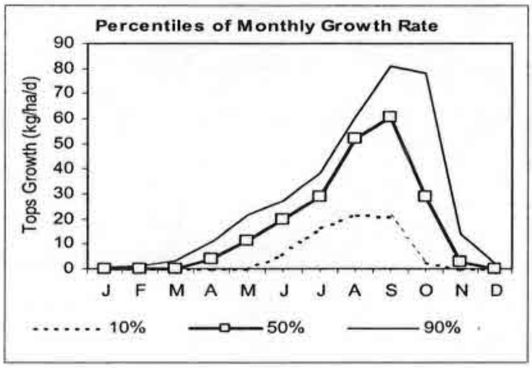


Roseworthy (SA)

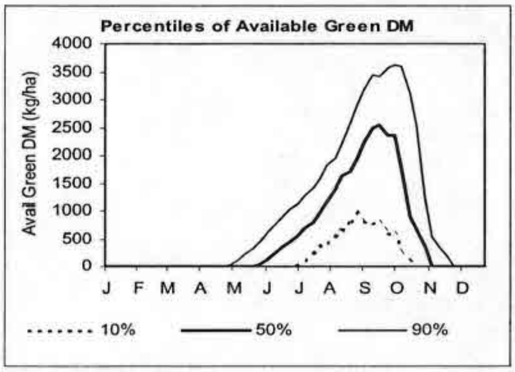
(a)



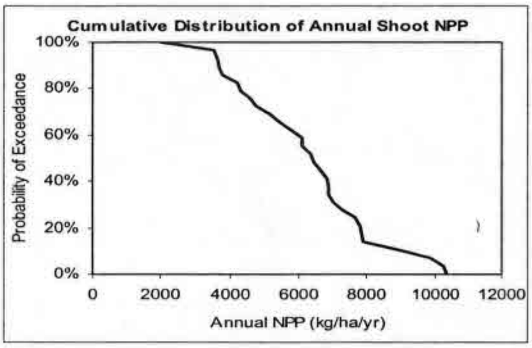
(b)



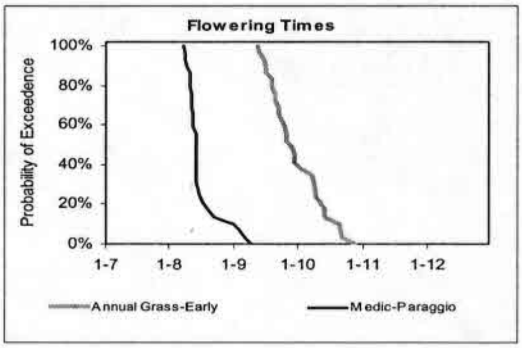
(c)



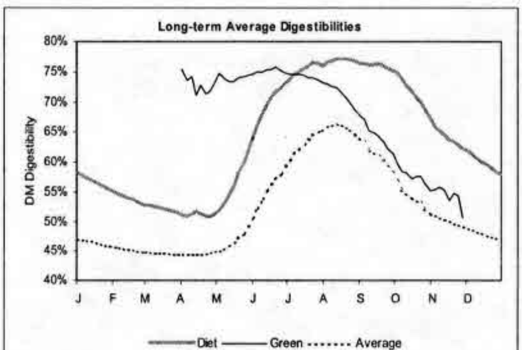
(d)



(e)



(f)



Pasture

Species composition

Mean pasture yield as NPP at Roseworthy was 6 t/ha and rarely exceeded 8 t/ha (graphs a and d). The early-flowering annual grass and Paraggio medic persisted over 30 years (a). The average proportion of each species was: annual grass 41% and medic 59%.

Growth

In half the years pasture growth rate exceeded 11 kg DM/ha/day in May, 29 kg DM/ha/day in July and 61 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from late May in half of all years; green pasture was present until mid-October in 90% of years and until the beginning of November in 50% of years. In half the years, 2.5 t/ha or more of green pasture was available at the peak of spring (c).

Quality

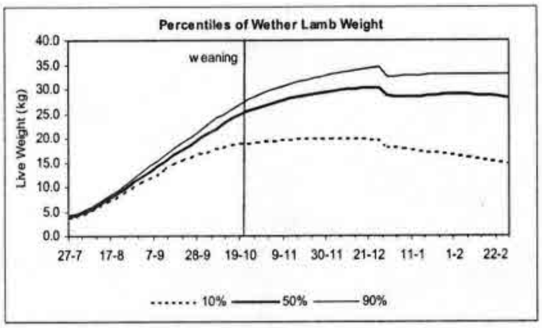
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). The average digestibility of the whole pasture exceeded 50% from June-mid November. The digestibility of green herbage declined from late June and fell below 70% in late August. Animals selected a diet that had an average digestibility of greater than 70% until late October.

Livestock

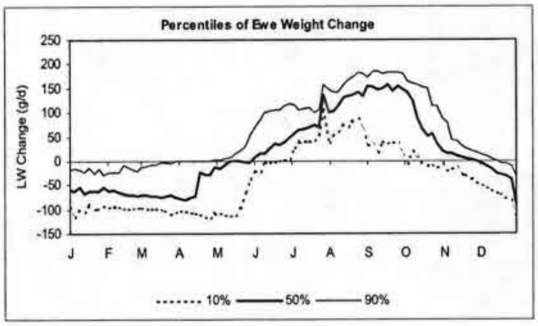
In half the years, the pre-weaning growth rate of wether lambs was at least 246g/head/day (24.9 kg live weight at weaning) (g). In most years weaners continued to gain weight until mid-December. (The dip in live weight at the end of December is due to shearing.) Thereafter pasture quality declined; median lamb live weight was maintained above 28 kg from early January until sale in late February.

In half the years, ewes lost weight between late November and June (h). Supplementary feeding of ewes spread over the first eight months of the year but was most likely to be required from mid-April to mid-June (j). Some supplementation of ewes was required in all but 2 of the 30 years simulated (i); in 50% of years the amount fed was less than 25 kg/ewe/year. Most feeding coincided with droughts in 1972, 1977-78, 1980-83, 1990, 1994-95 (a,i).

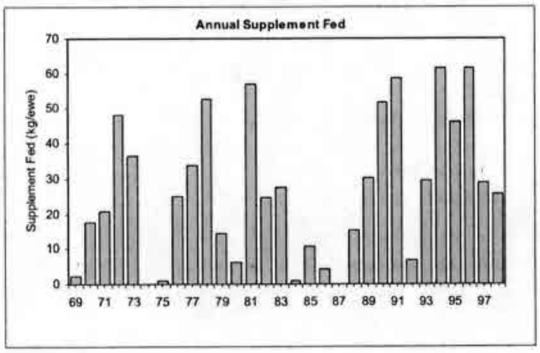
(g)



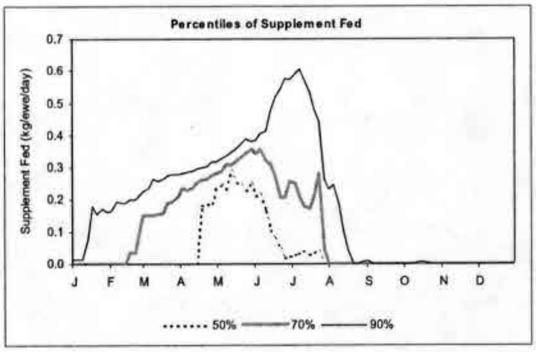
(h)



(i)

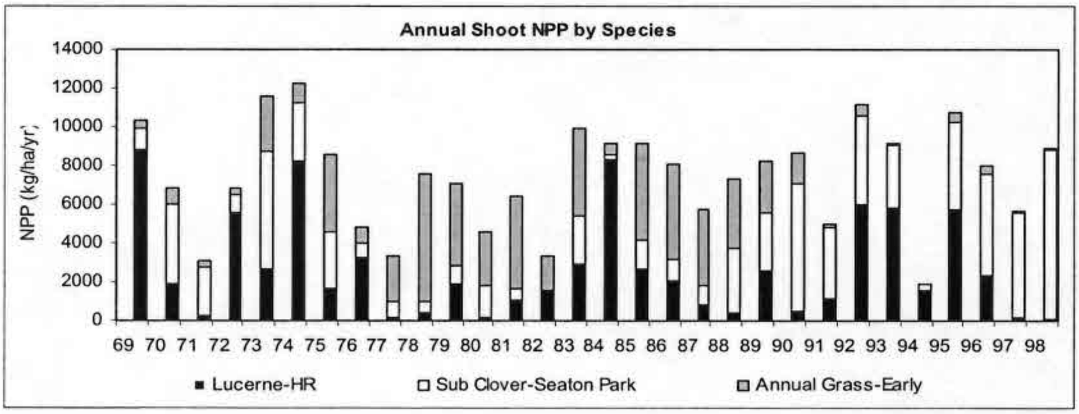


(j)

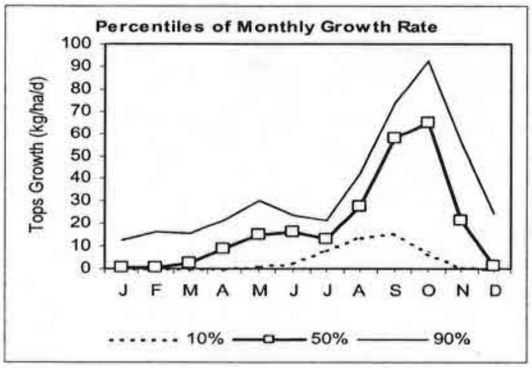


Temora, NSW

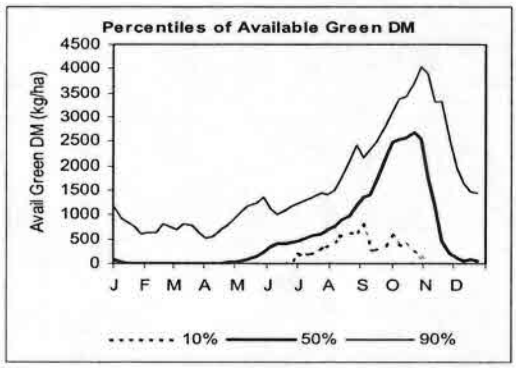
(a)



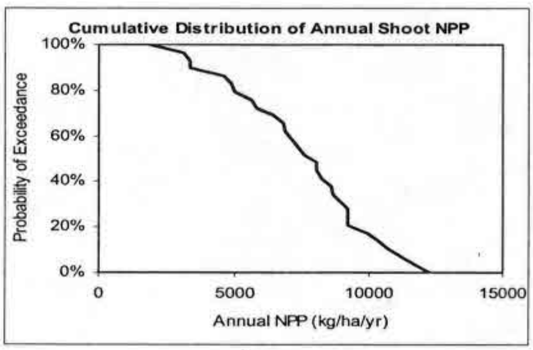
(b)



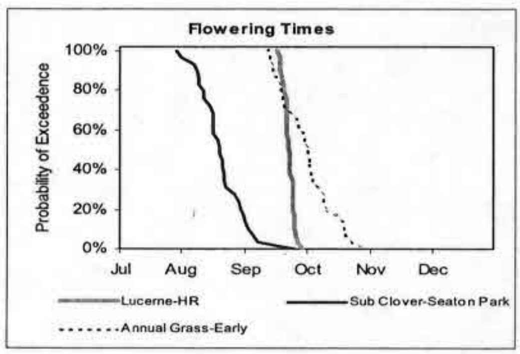
(c)



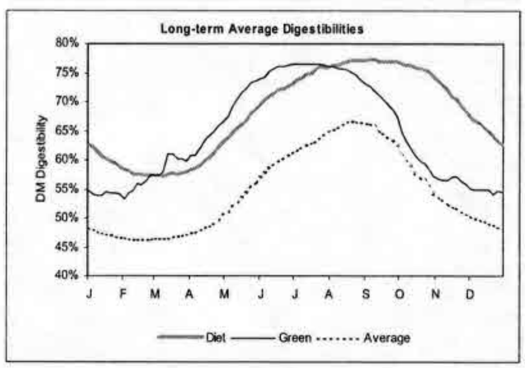
(d)



(e)



(f)



Pasture

Species composition

Mean yield as NPP at Temora was 7 t/ha and rarely exceeded 10 t/ha (graphs a and d). Each of the three species persisted over 30 years (a). The average proportion of each species was: lucerne 36%, sub clover 36% and early flowering annual grass 28%.

Growth

In half the years pasture growth rate exceeded 15 kg DM/ha/day in May, 13 kg DM/ha/day in July and 65 kg DM/ha/day at the peak of spring (b). Green pasture became available to livestock from early May in half of all years; green pasture was present until early November in 90% of years and until at least December in 50% of years. In half the years, 2.5 t/ha or more of green pasture was available at the peak of spring (c). In the wettest 10% of years lucerne provided about 800-1500 kg DM/ha of green pasture from December-April.

Quality

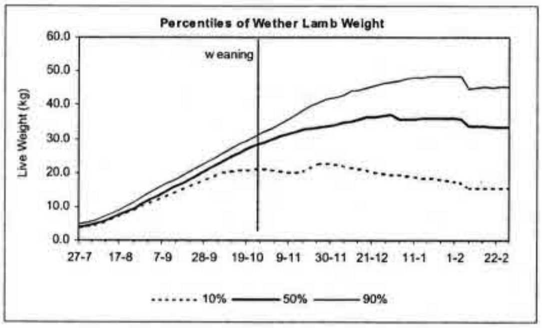
The digestibility of pasture throughout the year (f) reflected this distribution of green herbage and the flowering times of each species (e). The average digestibility of the whole pasture exceeded 50% from May-December. The digestibility of green herbage declined from late July and fell below 70% in late September. Animals selected a diet that had an average digestibility of greater than 70% until late November and green lucerne maintained the average digestibility of the diet above 55% during summer and autumn (however this was highly variable from year to year).

Livestock

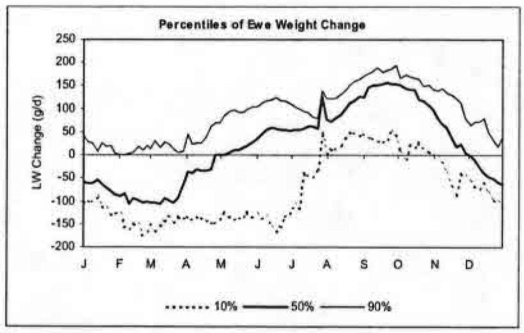
In half the years, the pre-weaning growth rate of wether lambs was at least 271 g/head/day (27.1 kg live weight at weaning) (g). This growth reflected the high legume content of the pasture. In most years weaners continued to gain weight until mid-December. (The dip in live weight at the end of December is due to shearing.) Thereafter median lamb live weight was maintained above 36 kg until sale in late February.

In half the years, ewes lost weight between mid-December and late April (h). Supplementary feeding of ewes took place at different times over the first eight months of the year but was most likely to be required from April to mid-May and during late pregnancy. Some supplementation of ewes was required in 24 of the 30 years simulated (i); in 50% of years the amount fed was less than 15 kg/ewe/year. Most feeding coincided with droughts in 1977, 1982, 1987,1991 and 1994 (a,i).

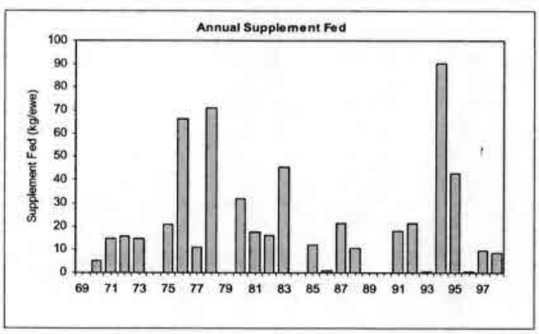
(g)



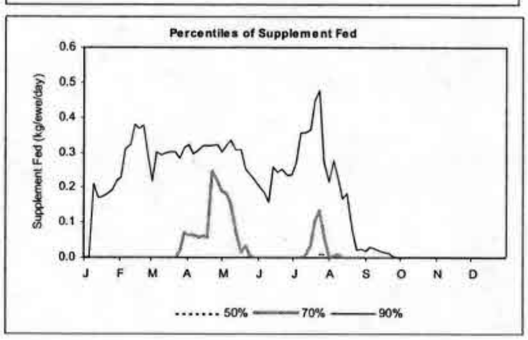
(h)



(i)



(j)



Appendix 1: Inputs to long term simulation at Canberra (Ginninderra Experimental Station)

Title:	Ginninderra Long Term
File:	C:\QA Sims 28 Nov 01\LT Test - Ginninderra Phalaris.grw.
Last Saved:	Thursday, 13 Dec 2001 12:55
Locality:	Ginninderra Experiment Station. Last built: 8 Jun 2001
Enterprise:	Ewe
No. Paddocks:	1
Simulation:	Historical from 1 Jan 1969 to 31 Dec 1998
Output:	Detailed
GrassGro Version:	2.4 32 bit
Last compiled:	Thursday 13/12/2001
	Research Version
Pasture Parameters:	GRASSGRO.GPP The internal date: 12 Dec 2001

Management

Stocking rate:	12.0 per ha		
Shearing date:	30 Dec		
Self-replacement:	1 Jan		
Cast for age at:	5+ years on 31 Dec		
Sell lambs on:	28 Feb		
Mating date:	1 Mar		
Birth date:	27 Jul		
First joining at:	1 years		
Conception at CS 3:	(1) 70% (2) 20% (3) 0%		
Castration:	Yes		
Weaning date:	20 Oct		
One ram per:	50 ewes		
Keep rams for:	5 years		
Maint. feeding:	in Paddock		
	when average C.S. < 1.5	or lowest C.S.	< 1.0 from 1 Jan
	when average C.S. < 2.0	or lowest C.S.	< 1.0 from 1 Jul
	when average C.S. < 1.0	or lowest C.S.	< 1.0 from 1 Sep
Weaner maint.:	in Paddock		
	when average C.S. < 1.0	or lowest C.S.	< 1.0
	100% Barley		
	DM 89% DMD 92% ME:DM 13.8 CP 14% Deg. 92%		

Costs & Prices

Fleece price	700 c/kg
Average:fleece price	90%
Commissions, wool tax etc	12.0%
Lamb prices	
Carcase price	120 c/kg DW
Carcase yield	45%
Skin price	3.00
C.F.A. prices	
Carcase price	60 c/kg DW
Carcase yield	45%
Skin price	1.00
Shearing cost	4.00 /head
Lamb shearing cost	3.00 /head
Husbandry cost	5.00 /head
Lamb husbandry cost	3.00 /head
Cost of replacements	40.00 /head
Cost of rams	250 /head
Commission on sales	5.0%
Other sale costs	1.20 /head
Cost of maint. supplt	150 /tonne
Cost of prodn supplt	150 /tonne
Cost of pastures	30 /ha

Livestock

Breed:	Med. Merino, Polwarth				
Std Ref Wt:	50.0 kg				
Pot Fleece Wt:	4.5 kg				
Max Fibre Diam:	21 microns				
Fleece Yield:	70%				
Ram breed:	Med. Merino, Polwarth				
Death rate:	2.0%/year				
Ewes:	Number	Months	Live Wt	GFW	Lamb Wt
	245	17		48.2	0.30
	240	29		50.4	0.30
	465	47		50.8	0.30
	------			-------	----
	950			50.0	0.30
Male weaners:	Number	Months	Live Wt		
	417	5	25.0		
Female weaners:	Number	Months	Live Wt		
	417 5	25.0			

Paddock 1

Area: 100 ha
Steepness: Level
Fertility: 0.90

	Cumul. Depth	Init. Water	Water F.C.	Content W.P.	Bulk Density	Sat. Cond.	Soil Evap.
Topsoil:	300	20%	31%	9%	1.17	30.00	3.5
Subsoil:	1000	31%	38%	28%	1.45	3.00	

	Live	Dead	Litter	Root	Root Depth	Seed	Phenology
Phalaris	200	2000	1000	2000	710	-	S. Dormant(0)
Sub Clover - Seaton Park	0	504	500	0	490	400	Senescent
Annual Grass – Early	0	500	0	0	490	400	Senescent