Evaluating the Value of Field Crops
AN ENVIRONMENTAL BALANCE SHEET FOR ALFALFA

Dan Putnam[1]

ABSTRACT

A 'balance sheet' of environmental positives and negatives for alfalfa is described and discussed. Additionally, the issue of water is examined in relation to its global economic value, and the additional benefits to the landscape. Alfalfa, California's largest acreage crop, and fourth largest in the US, clearly contributes quietly but significantly to a range of environmental goals. These are its ability to provide a rich habitat for wildlife, an insectary for beneficial insects, soil improving characteristics, N_2 fixation which conserves fossil fuels in agriculture, its ability to trap sediments and prevent water and air pollution, reducing the need for tillage, its ability to take up nitrate pollutants, high levels of CO_2 fixation to mitigate climate change, as well as to provide open space for aesthetic value. Among agronomists, farmers, and knowledgeable wildlife experts, the inclusion of alfalfa into crop rotations is considered to be highly positive environmentally. However, there are negatives as well. The key negatives of alfalfa pertain to its high total water use and the possibilities of off-site movement of pesticides. The primary critique of alfalfa in the West pertains to its water use in relation to its economic value. However, this critique underestimates the full economic value of alfalfa, which is worth over $1 billion/year and linked to 25% of California's agricultural economy. It receives no price subsidy and must compete economically for water with many other higher value crops. Alfalfa produces the equivalent about 2400 gallons of milk/acre, or over $7,000 of consumer value per acre (similar to almonds). Alfalfa also has several features which are positive with regards to its water-use particularly high water use efficiency, and ability to sustain production during droughts. With a water-scarce future, farmers and researchers clearly must improve forage systems to reduce water demand and protect water and air quality. However, alfalfa should be recognized for its important role in sustaining agricultural systems, now and for the future.

Keywords: Environmental issues, water use, pest management, wildlife, insecticides, herbicides, water quality, mitigation, nitrates.

WHAT IS THE CHALLENGE?

Some see agriculture as diametrically opposed to environmental goals. However, many types of agriculture make significant contributions to ecosystem health. Rice, for example, is a critical component of the flyway of many migratory and non-migratory birds. Pastures and grasslands can clean up water quality and stabilize soils. Grazing animals can remove invasive weeds and suppress devastating fire. Sudangrass, corn and alfalfa take up considerable quantities of nitrate from contaminated water. Agriculture can degrade the environment, but it also provides solutions to environmental problems.

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[1] Dan Putnam, Forage Specialist, University of California, One Shields Avenue, Davis, CA 95616, dhputnam@ucdavis.edu. IN Proceedings, 2010 California Alfalfa & Forage Symposium and Corn/Cereal Silage Mini-Symposium, Visalia, CA, 1-2 December, 2010. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616. (See http://alfalfa.ucdavis.edu for this and other alfalfa symposium Proceedings)

A profound challenge faces our world in the future—we must determine how to feed, clothe, and provide renewable energy for an additional approximately 3 billion additional people (the UN predicts 8.9 billion by 2050), while reducing agriculture's impact on land, water, and the earth's biota, while mitigating the potential effects of global climate change—likely on the same arable land area than is currently used now.

A critical component of this challenge is the issue the 'value', or lack thereof, that is placed on agriculture by our economic and political system. Economics primarily dictate cropping decisions, but policy and public pressures also play an important role. This is a tremendous challenge, especially as we witness the relentless conversion of agricultural land into urban uses all over the United States, and indeed the world. This issue is especially critical in California where some of the most productive areas of the state are seeing unprecedented urban expansion. Envisioning agricultural systems that can resist excessive urbanization, produce abundant food, and protect the environment is a tremendous challenge to farmers, policy makers, and scientists. This paper explores the issue of 'value' (both economic and environmental) when it comes to the impact of alfalfa, and presents a balance sheet of the positive and negative aspects of alfalfa from an environmental perspective.

ECONOMICS AND VALUE IN RELATIONSHIP TO APPLIED WATER

The question of economic value of field crops in relationship to their water use is a considerable component of the debate over how to address the water needs of the future, and the environmental impacts of agriculture. To paraphrase several of these arguments:

> *'Water should be shifted (either through policy or economics) from crops that have high rates of applied water and low income per unit land area, to those crops which use less water or to other uses, such as the environment. '*

Although this argument pertains to field crops in general, alfalfa is often the 'poster child' of this critique. These arguments have mostly come from environmental groups and think tanks (e.g. Cooley et al., 2008). Often, this comes out as clearly as an 'urbanize the landscape' viewpoint:

> *Agriculture now uses approximately 80 percent of California's developed water supply, but produces less than 2.5% of California's income. An alfalfa farm using 240 acre-feet of water generates $60,000 in sales, while a semiconductor plant using the same amount of water generates 5,000 times that amount, or $300 million. -Alfalfa: The Thirstiest Crop, Natural Resources Defense Council, 2004*

This is a curious statement, especially coming from a supposedly pro environmental group. It's curious not because it is incorrect, but since it so clearly advocates shifting of water from any use (environmental or agricultural) that can't compete with an urban factory. The argument is primarily monetary, not environmental.

Is this question of 'low value' crops really a question of the (more subjective) values that are held by some in the non-farm public? Is it an argument that holds up based upon either economic or environmental criteria?

Consider the following points related to the 'low value' critique of alfalfa:

- **Alfalfa has high 'global' economic value** to the state – worth over $1 billion/year and linked to 25% of the state's agricultural product (forages, dairy, and beef). Thus, the 'low value' moniker doesn't quite hold up to scrutiny.
- **In spite of the 'low value' description, alfalfa must compete economically for water** and land resources directly and equally with all crops, including high- and low-value crops. It receives no crop subsidy, and follows fairly closely free market conditions.
- **Farmers make rational choices.** Farmers have already made rational economic decisions about the most appropriate crops for their farm, based upon their soils, climate, infrastructure, money for investment, and risk tolerance. They would (and will) grow higher value crops as their conditions permit.
- **High Value and High Risk.** Common sense and economic theory would not favor enterprise strategies (or agricultural policies) that only favor high risk investments, such as wholesale shift to specialty crops. Mixed strategy of both high-and low-value crops on farms is important to stabilize income and sustain agriculture.
- **Overproduction of 'high-value' crops.** Policies which artificially encourage shifting to higher value crops for policy reasons risk overproducing these crops for narrow markets – a common problem with specialty crops.
- **Cash Flow Economic Benefit.** Alfalfa provides considerable 'cash-flow' economic benefits to farm enterprises, paying many bills from the monthly income from the 3-10 harvests throughout the year, unlike crops which provide income only once per year.
- **Water Use Efficiency**. Some of our highest value specialty crops are actually much lower in water use efficiency (unit of economic product produced per unit of water) than our so-called 'low value crops'.
- **Water Demand Depends upon Acreage.** Shifting to 'high value crops' would not guarantee a savings of water, since this depends upon acreage. If demand for high value crops soars and the same total land area is cultivated, water use could increase, not decrease in a region.
- **Contribution to human health, food production.** While specialty crops offer tremendous diversity to diets, it's the humbler agronomic crops that provide the staple foods for millions in their daily lives: wheat, rice, milk, meat, oilseeds.
- **Complex Economic Benefits.** Some 'low value' crops provide economic benefits beyond their direct value. (Examples: cover crops, wheat in rotation to suppress disease, alfalfa to provide N to subsequent crops or to transition to organic agriculture.)
- **Low Cost Food Benefits Industrial Society.** While most farmers complain that ag. products are too cheap, inexpensive food is a major driver for industrial growth - silicon chip factories, for example – consider the limited buying power of a society that pays 60% of its income for food, rather than the current 8% for the US.
- **Additional Economic and Non-Economic Values.** A narrow acre-to-acre estimation of economic value ignores other values (such as benefits to the environment and contribution to human nutrition) but also the more global monetary value of the enterprise: to the whole food system and to the consumer.

BROAD ECONOMIC VALUE OF ALFALFA

Alfalfa is not the highest revenue-generating crop in our state, but it's no slouch either. Alfalfa and other hays have been worth over $1 billion to the state in recent years (1.8 billion in 2008) in direct farm gate value (Table 3). Alfalfa alone has been shown to be worth $1.06 billion per year for the past 30 years in California, expressed in 2009 dollars. But more importantly, the farm gate value does not represent the more 'global' economic value of alfalfa. It is linked to two other major revenue-producers, milk and cream and cattle and calves (Table 3). These agricultural products (dairy, cattle, and alfalfa) account for more than 25% of the state's agricultural revenue, not including the multiplier effects of dairies or crop production.. California is the leading US producer of milk, providing about 21% of the US supply – and the primary starting point is alfalfa. In the US, alfalfa hay and other hays constitute the third most important economic product in the United States.

Table 3. Top Ten California Commodities in revenue, 2007-2008.

Commodity	2007	2008
Milk and Cream	7,337,603	6,924,121
Grapes (wind, raisin, table)	3,075,614	2,937,838
Almonds (shelled)	2,401,875	2,343,200
Nursery Products	2,961,891	2,273,500
Cattle and Calves	1,784,101	1,822,856
Hay (alfalfa and other)	1,405,800	1,797,032
Lettuce (all)	1,697,278	1,580,831
Berries (all including strawberries)	1,410,652	1,578,185
Tomatoes (all)	1,223,435	1,317,312
Rice	707,681	1,183,325
Total California	**36.4 Billion**	**36.2 Billion**

Economic Multiplier Effects. In addition to being closely linked to 25% of the state's revenue, there are numerous multiplying effects. For alfalfa, there are few studies to illustrate this. But the multiplier effects of alfalfa production clearly include the seed industry, trucking, ag chemicals, equipment manufacturers, testing labs and other services. On the dairy side, industry experts estimate that (in addition to the direct farm-gate value), CA dairies produce:

- 445,574 jobs (3% of CA job production)
- $63 billion in added economic activity (milk tank drivers, grocery clerks, etc.)
- This is greater than some CA economic powerhouses, such as
    - TV/Movies ($35 billion, 208,230 jobs)
    - Wine ($59 billion/330,000 jobs) (J/D/G Consulting, 2010)

Alfalfa is similar as an industry to steel or other basic industries, which impacts a wide range of enterprises. It is the basis for many economic activities, from cheesemaking to beef production, horseracing, to a local Taco Bell, and even honey production.

Water-Use Efficiency (WUE). It is important to evaluate the efficiency of water use by our various crops. The total per-acre water demand is not as important as how much production is obtained per unit of water. However, such comparisons require some careful thought about what is important: productivity, nutrition, economics, or other factors, such as integration with environmental goals. Alfalfa is one of our most water use efficient crops, since 100% of the above-ground portion of the crop is harvested, it is a perennial, and the yields are high. Comparing two important crops in California, alfalfa and almonds is revealing, since their water use per acre is similar. Although crop dry matter yields of alfalfa (harvested product) are more than 6 times those of almond, farm-gate revenues are lower (Table 2). This means that WUE (yield of economically-valuable product per unit of applied water) is far superior for alfalfa compared with almonds. However, the economic return to the farmer per unit of applied water is superior for almonds (Table 2), not considering risk factors. But is farm-gate value the only economic criteria that should be applied? What about the value to the consumer?

A Question of Value. Another way to look at this is the value that the public might realize from the use of a public resource (water). This perhaps gets to the heart of the 'low value vs. high value' crop discussion. Alfalfa and almonds are two major crops grown in California. Common consumer products from these two crops might be a gallon of milk or a can of almonds. Using average figures taken from public sources, an alfalfa crop can produce 2,459 gallons of milk/acre, and an almond orchard 1,646 cans of nuts/acre. Though the WUE of alfalfa (lbs produced per unit water) is superior, the economic yield to the grower per unit of water for almonds is superior. However, the value of the consumer products produced per acre is only marginally better for almonds—they are basically in the same general ballpark.

This comparison, of course, just compares some of the common products, for example milk, not the higher-value cheeses and other products made from it – nor the higher value products made from almonds. Nor are the 'mulitplier' values of these products considered. It also does not compare the nutritional value of the different crops per unit water, or the impact on daily diets of various foods. But it clearly illustrates several things:

- The tremendous productivity of California farms, benefitting the consumer.
- The impact of water per unit of economic value is far greater than just farm-gate value.
- The economic WUE based upon consumer value of both high and low-value crops may be similar, at least in some cases.
- The practice of utilizing primarily economic criteria, narrowly defined as farm-gate value, to make environmental judgments is open to question.

Table 1. Acreage, yield, Water Use, Price, Value, and Water Use Efficeincy and value of common consumer products of alfalfa and almonds in California.

Farm Production					Products produced: Value to the Public				Water USE and Efficiency			
Crop	CA Acreage	Crop Yield	Farm Gate Value		Most Common Retail Product	Product Units Produced	Price Per Unit	Consumer Value, Acre Basis	Crop Water Use	Water Use Efficiency (Economic Product Yield (DM) per unit water)	WUE (Economic-Based on Farm Gate Value)	WUE (Economic-Based on Consumer Value)
	acres	lbs/a	$/pound	$/acre	Item	Per acre	$/unit	$/acre	AF/A	lbs/AF	$/AF	$/AF
Alfalfa	980,000	13,800	$ 0.08	$ 1,104.00	Bottle of Milk (gal.)	2,459	$3.07	$7,550	4.09	3,374	$ 269.93	$1,845.85
Almonds	646,000	2,058	$ 1.86	$ 3,827.88	Nuts in a Can (1 lb)	1,646	$4.50	$7,409	3.26	631	$ 1,174.20	$2,272.64

**Notes: Production data from NSDA-NASS sources, retail data based upon US Consumer Price Index (5 year averages). Milk production/acre is from UW milk/acre calculation. Assuming an 80% field-product efficiency for almond. Water use is from DWR data*

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While an economic comparison evaluates monetary returns, is that the only value of crops to the public? Are there environmental services that could reasonably be ascribed to alfalfa? Agriculture interacts in a much more complex way with the environment than, say a factory, an office, or a waste treatment plant. Farms have intrinsic value beyond just their importance in producing food and fiber.

Below, I've listed several characteristics of alfalfa that produce value to landscapes (Table 3). In addition, the listing of wildlife that utilize alfalfa is provided (Table 4). Most of these specific issues have been covered in detail elsewhere (Putnam et al., 2001), and are summarized here. The development of an 'environmental balance sheet' seems appropriate, since no practice or enterprise may be conceived of as entirely positive or negative—all technologies typically have both negative and positive impacts.

REFERENCES

Putnam, D.H., M. Russelle, S. Orloff, J. Kuhn, L. Fitzhugh, L. Godfrey, A. Kiess, R. Long. 2001. Alfalfa, Wildlife and the Environment—The Importance and Benefits of Alfalfa in the 21st Century. California Alfalfa & Forage Association, Novato, CA (see http://alfalfa.ucdavis.edu)

Table 3. An Environmental Balance Sheet for alfalfa.

Issue	Positives	Negatives
Soil Protection		
Soil Erosion	(+++) Alfalfa is one of the best crops for holding soil in place, compared with row or orchard crops.	(-) Some minor erosion takes place at the ends of fields in flood irrigated fields, or in patches with poor stands.
Nitrate Contamination of groundwater	(+++) Due to its high protein content, high yield, and extensive root system, alfalfa can absorb large quantities of nitrate if present in the soil solution.	(-) The biologically-fixed N from alfalfa could contaminate groundwater, if the following crops in rotation cannot access this N.
Soil Quality	(+++) Alfalfa is well known to improve soil quality (tilth), water infiltration, nitrogen status of the soil, and rhizosphere biological activity. Alfalfa is highly valued by organic and conventional farmers alike.	(-) Equipment traffic in alfalfa can increase soil compaction, necessitating occasional deep tillage
Air and Climate		
Air Quality	(+++) Alfalfa's extensive roots and vigorous canopy prevents wind erosion (dust), reducing particulates, and produces oxygen to purify the air.tillage is only needed at planting,	(-) Some of the pesticides used in alfalfa can contribute to Volatile Organic Compound (VOC) emissions.
Climate Change/Energy/ Fossil Fuels	(+++) Alfalfa is considered a powerhouse of CO_2 fixation, and reduces the fossil fuel impacts of agriculture due to zero need for N from fossil fuels. Alfalfa is a potential biofuel.	(-) Equipment used to harvest and transport alfalfa contributes to fossil fuel use in agriculture.
Water Conservation and Quality		
Water Demand	(+) Alfalfa can be deficit irrigated in emergency to conserve water during drought years without killing the crop, enabling water to be used for other purposes.	(---) Alfalfa's demand is high, reducing water that can be used for other purposes, including environmental uses.
Water Use Efficiency	(+++) Alfalfa is one of the most water use-efficient crops, needing less water per pound of dry matter yield than most crops. Its deep roots prevent loss of water from the root zone, and it requires less water for stand establishment.	(-) Irrigation systems, crop yields, and management can be improved to further increase WUE for alfalfa.
Water Quality, Pesticide Use, Contamination of water	(+++) Alfalfa prevents particulates from contaminating waterways. Alfalfa is relatively low in pesticide use compared with most other crops – varieties with a wide range of pest resistance are available to reduce pesticide use.	(--) Some insecticides and conventional herbicides used in alfalfa have been found in surface and groundwater. However, this is primarily a problem with surface runoff.
Biological Diversity		
Insect Diversity	(+++) Alfalfa is one of the most productive insectaries known in agriculture, with up to 1,000 species observed. It is a source of beneficial insects for neighboring crops.	(-) Some of the insecticides used in alfalfa can reduce beneficial insects. Alfalfa is also a source of insects that infest other crops, necessitating treatment.
Wildlife Habitat	(+++) Alfalfa provides significant wildlife habitat for many types of birds, amphibians, and mammals, including several endangered and threatened species.	(-) Unfortunately, the frequent harvests of alfalfa can injure wildlife or reduce habitat. On the other hand, harvests benefit some wildlife, such as raptors.

***Note:** *This listing is provided as a qualitative analysis of alfalfa's role in the environment. Quantitative evidence has been published for most, but not all of these statements.*

Table 4. Listing of Wildlife Species which utilize alfalfa as habitat. Of the 675 regularly-occurring resident and migratory wildlife that live in California, 182 species (27%) use alfalfa. These creatures use alfalfa for Reproduction (R), Cover (C), or Feeding (F). Degree of suitability is either high (***), medium (**), or low (*). List compiled by Dr. Lee Fitzhugh, Wildlife Biologist, UC Davis. (Putnam et al., 2001)

BIRDS	USE OF ALFALFA		
Species	R	C	F
American Avocet	*	**	***
American Coot			***
American Crow			***
American Goldfinch			**
American Kestrel		***	**
American Pipit		***	***
American Robin			**
American Widgeon	*	*	**
Ash-throated Flycatcher			**
Bank Swallow			***
Barn Owl		***	***
Barn Swallow	**	**	***
Black Phoebe		**	**
Black Tern		*	***
Black-bellied Plover		***	***
Black-billed Magpie			***
Black-crowned Night Heron		**	***
Black-necked Stilt		*	**
Blue Grosbeak		**	***
Blue-winged Teal		*	**
Brewer's Blackbird	*	**	***
Brewer's Sparrow		**	**
Bronzed Cowbird			***
Brown-headed Cowbird			***
Burrowing Owl	***	***	***
California Gull		***	***
California Quail	**	**	***
Canada Goose	*	***	***
Cattle Egret		***	***
Cinnamon Teal	**	**	**
Cliff Swallow	**	**	***
Common Ground Dove		**	**
Common Nighthawk			***
Common Raven			***
Common Snipe		**	**
Dark-eyed Junco		**	**
Dunlin	*	*	
European Starling			***
Ferruginous Hawk			***
Fulvous whistling duck		**	***
Gadwall	**	**	*
Golden Eagle			***
Golden-Crowned Sparrow		**	**
Great Blue Heron		***	***
Great Egret		***	***
Great Horned Owl			***
Greater Roadrunner		***	**
Greater White Fronted Goose		***	***
Greater Yellowlegs		*	**
Great-tailed Grackle			**
Green Heron			***
Green-winged Teal		*	**
Gull-billed Tern			***
Harri's Sparrow		**	**
Herring Gull		**	**
Horned Lark		**	***
House Finch		**	***

BIRDS	USE OF ALFALFA		
Species	R	C	F
House Sparrow		***	***
Inca Dove	*	**	**
Killdeer	***	***	***
Lark Sparrow	**	**	**
Lawrence's Goldfinch			**
Least Sandpiper		***	***
Lesser Goldfinch		**	**
Lesser Nighthawk			***
Lesser Yellowlegs		*	**
Lincoln's Sparrow		**	**
Loggerhead Shrike		**	**
Long Eared Owl			***
Long-billed Curlew	***	***	***
Long-billed Dowicher		***	***
Mallard	***	***	***
Marbled Godwit		**	**
Marsh Wren		**	**
Merlin		**	***
Mountain Bluebird		***	***
Mountain Plover		***	***
Mourning Dove			**
Northern Flicker			***
Northern Harrier	***	***	***
Northern Mockingbird			**
Northern Pintail	***	***	***
Northern Pygmy Owl			***
Northern Rough-winged Swallow			***
Northern Shoveler	*	*	
Northern Shrike		**	***
Peregrine Falcon		*	**
Pine Siskin			**
Prairie Falcon		*	***
Purple Martin			***
Red-Shouldered Hawk			***
Red-tailed Hawk	*	*	**
Red-winged Blackbird			***
Ring-billed Gull		***	***
Ring-Necked Pheasant	***	***	***
Rock Dove			**
Ross' Goose		***	***
Rough-Legged Hawk			**
Ruby-Crowned Kinglet			***
Sandhill Crane	***	***	***
Savannah Sparrow	**	**	**
Say's Phoebe		**	**
Scrub Jay			**
Short Eared Owl	*	***	***
Snow Goose		***	***
Snowy Egret		**	**
Spotted Sandpiper			**
Swainson's Hawk			***
Tree Swallow			***
Tricolored Blackbird			***
Tundra Swan		***	***
Turkey Vulture			**
Vermillion Flycatcher		*	***
Vesper Sparrow	*	**	**

Table 4. Listing of Wildlife Species which use alfalfa in California (continued).

BIRDS	USE OF ALFALFA		
Species	R	C	F
Violet-green Swallow			***
Western Bluebird			**
Western Kingbird			***
Western Meadowlark	***	***	***
Western Sandpiper		***	***
Western Screech Owl			***
Western Wood Pewee			**
Whimbrel		***	***
White Tailed Kite			***
White Throated Sparrow		**	**
White-Crowned Sparrow		*	**
White-Faced Ibis		*	***
Wild Turkey			**
Willet		**	*
Wilson's Phalarope	*	***	***
Wilson's Warbler			**
Wite-winged Dove			**
Yellow Warbler			**
Yellow-billed Magpie			***
Yellow-Footed Gull		*	**
Yellow-headed Blackbird			**
Yellow-rumped Warbler			**

MAMMALS	USE OF ALFALFA		
Species	R	C	F
American Badger	*	*	**
Arizona Cotton Rat	***	***	***
Belding's Ground Squirrel	*	**	***
Big Brown Bat			**
Black Rat	**	**	**
Black-tailed Jackrabbit	**	**	***
Bobcat			**
Botta's Pocket Gopher	***	***	***
Broad-footed Mole	**	**	**
Brush Rabbit	**	**	***
California Ground Squirrel	*	**	***
California Myotis			**
California Vole	**	**	***
Coyote	*	*	***
Creeping Vole	*	**	***
Deer Mouse	*	**	**
Desert Cottontail	**	**	***
Elk			***
Feral Ass		*	***
Feral Cat	*	**	**
Feral Dog	*	**	***
Feral Horse		*	***
Feral Pig		*	***
Gray Fox		*	***
Hispid Cotton Rat	***	***	***
House Mouse	*	*	**
Kit Fox		**	***
Long -Tailed Vole	**	**	***
Long-tailed Weasel	*	*	**
Mexican Freetailed Bat			***
Montane Vole	**	**	**
Mountain Pocket Gopher	***	***	***

MAMMALS	USE OF ALFALFA		
Species	R	C	F
Mule Deer		*	***
Northern Pocket Gopher	***	***	***
Norway Rat	**	**	**
Pallid Bat			***
Pronghorn	*	***	***
Raccoon		*	**
Red Fox	*	**	***
Ringtail		*	**
Silver-haired Bat			**
Striped Skunk		*	***
Townsend's Ground Squirrel	*	**	***
Townsend's Mole	**	**	**
Townsend's Vole	*	**	***
Virginia Opossum	*	*	**
Western Harvest Mouse	**	***	***
Western Mostitt Bat			***
Western Pocket Gopher	***	***	***
Western Red Bat			**
White-tailed Jackrabbit		*	***
Yuma Myotis Bat			**

OTHER	USE OF ALFALFA		
Species	R	C	F
Checkered Garter Snake	***	***	***
Common Garter Snake	**	**	**
Common Kingsnake	**	**	**
Gopher Snake	***	***	***
Racer Snake	*	*	*
Western Fence Lizard	**	**	**
Western Toad	***	**	**