Report of the Advisory Committee on Alternatives to Rice Straw Burning

December 2001

EXECUTIVE SUMMARY

During the period of 1997 to 2000, many California rice growers, and several public and private agencies expended an enormous amount of time, energy and expense to increase rice straw utilization. In spite of these efforts, the level of straw use remains disappointingly low, from 1-4% of the total straw available. Legislation (SB 318, 1997) set a goal of 50% utilization by 2000. A rice straw diversion plan, issued in December 1998, concluded 50% usage was not likely without very significant and expensive public intervention, but with no intervantion 20% might be utilized by 2003. SB 318 also supported demonstration of rice straw utilization technologies through the Rice Straw Demonstration Project Grant Fund. Approximately $5 million has been expended since 1998, with another $900,000 to be awarded in the fiscal year 2001-2002. Each funded project holds promise although only one has become commercial. One of the largest potential uses of rice straw is for ethanol production, seemingly given impetus by the phaseout of MTBE as a fuel additive, but possibly postponed as a result of concern about the adequacy of the supply of complying gasoline. A rice straw end users tax credit program (SB 318, 1996) grows annually but the amount of straw used remains relatively small and dependent on this subsidy.

Research, primarily by the University of California, is developing a better understanding of the costs, methods and equipment for harvesting, handling and storing rice straw, including characterization of rice straw for end uses. Other UC research is developing information on straw's value as livestock feed, and the effects of in-field management of straw on agronomics and pest management aspects of rice production. Rice Fund grantees and other entrepreneurs are also doing much research and development for their particular processes, and there is much promise of increased use in the future. However, the near term outlook for substantial increase in use is poor, constrained by technology gaps, the high cost of feed stock acquisition and the effect of both on availability of risk capital. Current major uses include medium density fiberboard, livestock bedding, livestock feed, and sediment and erosion control.

Lacking alternatives for rice straw disposal, rice growers incorporate back into the soil approximately 70% of their straw at considerable additional expense. In addition, research and field experiences have demonstrated that soil incorporation may result in increased disease problems and the possibility of increased weed pressure. These, in turn, may result in lower rice yields. Many rice growers feel their business slipping away from them as their costs increase and their profits go down. For long term economic sustainability, there is a strong feeling of urgency to increase straw use, not just as a disposal alternative but for revenue generation. For long term production sustainability, over-reliance on a single method of straw management is undesirable. A mix of management methods, including soil incorporation, utilization and burning should be available and a stated goal of policy-makers.

Utilization of rice straw is severely constrained by the lack of an efficient straw handling infrastructure, including harvesting capacity, trucking, storage and consistency of supply. The Committee examined the existing infrastructure and identified barriers and recommended solutions. Emphasis was placed on the need to develop storage capacity consistent with end uses.

The Committee made several recommendations:

1. *Encourage the State of California to support the use of ethanol derived from agricultural waste, as a fuel and fuel oxygenate to replace MTBE, and for other uses, if environmental, technical and economic studies are supportive.*

2. *The Committee supports consideration of several government intervention or industry-supported measures suggested by the Rice Straw Diversion Plan:*

- *Conduct or support studies on straw supply potential, current supply of straw, options and costs of methods and equipment, storage, transportation, standards and grades*
- *Conduct or support studies on potential for secondary straw market such as compost and anaerobic digestion*
- *Provide information and administrative assistance to develop straw cooperatives and straw distribution and marketing centers*
- *Provide financial resources for end-user businesses, such as 30% loan guarantees, low interest loans, accelerated capital depreciation, or 50% matching grants*
- *Provide financial resources for research projects to address technical barriers so that results are in the public domain*
- *Provide resources to develop a Rice Straw Business Assistance Program to help new business access financial and educational assistance*
- *Encourage state agencies to use and promote rice straw products where such use would be appropriate*

3. *Expand the Rice Straw Utilization Tax Credit Program by lifting the annual $400,000 cap to attract larger and more diverse projects; allow trading of tax credits so users of rice straw with no California tax liability will be encouraged to invest; dedicate the unused tax credit each year to other activities to support utilization; and allow 'forward contracting' of rice straw so that users will know if they are eligible for the tax credit prior to harvesting the straw. Allow growers to use their own straw and take the tax credit.*

4. *California Dept. of Housing and Community Development undertake and complete seismic, structural, fire, and insulation tests of rice straw bales intended for construction purposes and incorporate the results in the Uniform Building Code of California.*

Standards for 'construction grade' rice straw bales should be developed and adopted by industry.

5. All stakeholders, including growers, end-users, and public agencies recognize the need for a *long-term straw management goal to enhance the sustainability of rice production. Complete reliance on a single system of rice straw management is undesirable and a blend of straw management alternatives should remain available. These alternatives include soil incorporation, baling and removal, and burning, which can be used in a rotational sequence.*

6. *Users of rice straw should be aware that supplies vary on an annual basis and are encouraged to project their needs over several years and plan a prudent reserve*. *The Committee supports the recommendations of the draft report "Recommendations for Ensuring the Consistency and Predictability in the Supply of Rice Straw for Cost-Effective Uses". This draft report can be found on the ARB website at www.arb.ca.gov/smp/rice/supply/supply.htm.*

7. *Research is needed on technology and economics of specialized rice straw harvesting equipment to accommodate the higher wear rate and wet soil conditions in rice fields*.

8. *Government assistance, similar to the Rice Straw Utilization Tax Credit program, should be investigated to stimulate the construction of storage structures for rice straw. Such a program should have a sunset to get the process started after which market mechanisms would determine the economics of building storage*.

9. *Research on optimizing placement of storage facilities should be encouraged.*

10. The State of California should initiate development of industry specific standards and grades for rice straw, involving industry in the process.

INTRODUCTION

The ongoing mission of the Advisory Committee on Alternatives to Rice Straw Burning is to provide a forward-thinking forum to hear and comment upon proposed and/or progressing alternatives to the burning of rice straw. The authority for the Committee was created by the rice straw phase-down legislation, which enacted Health and Safety Code, Section 41865 (l) (1). The committee has existed since 1992 and is appointed jointly by the California Air Resources Board (ARB) and the California Department of Food and Agriculture (CDFA). The purpose of the committee is to assist with the identification and implementation of alternatives to rice straw burning, by developing "a list of priority goals for the development of alternative uses of rice straw for the purpose of developing feasible and cost-effective alternatives to rice straw burning." The law requires the committee to meet at least annually, although it meets approximately six times yearly. Membership is composed of two rice growers, two representatives from the environmental community, two health officials, two county supervisors or their designees, one member from the air pollution control council and one member from the business community with expertise in market or product development. Meetings are supported by ARB and CDFA staff.

The first report of the Committee in 1995 provided a comprehensive overview of the status of rice straw utilization, with detailed descriptions of potential straw utilization processes and business, with analysis of technical and economic feasibility and evaluation of commercial potential. Extensive discussion of infield management of rice straw, primarily soil incorporation, was included. The 1997 report used a similar format and updated the first report. Recommendations were included in both reports. The current report includes:

1. A brief statement of change and progress during the past two years. Extensive description and analysis of processes that was contained in previous reports is omitted. Readers should refer to previous reports for this information.
2. A discussion of the status of rice straw marketing infrastructure in California. The 1997 report noted that "in the absence of an efficient marketing mechanism, the diversion of rice straw to any of the off farm alternatives could be severely constrained." The committee focused its efforts during the reporting period on this central issue which affects all uses. In gathering information for the report, the committee had extensive discussion with numerous stakeholders, and input from practitioners and other experts. Recommendations on infrastructure are included.

SUMMARY OF RICE STRAW MANAGEMENT PROGRESS AND CHANGES, 1997-2000

Progress in utilization of rice straw is disappointingly low and was only 1-2% of the total supply in 1997 and 1998, and rose to 3-4% in 1999 and 2000. The potential exists for several businesses to come on line over the next two years. For example, a moderate-size commercial facility, FiberTech USA, Inc., which makes medium density particleboard, began production in late 1999. In addition, legislation/government assistance, public research and private efforts since the last Rice Straw Alternatives Advisory Committee report are gradually positioning the California rice industry to begin using significant quantities of rice straw. Economic, technical, infrastructure, and public policy (on ethanol use) barriers, however, remain before large amounts of rice straw can be utilized. The rate of increase in rice straw usage will likely remain low until some of these barriers are overcome and a few large-scale users can come on line. Following are brief accounts of events and activities related to rice straw management, from mid-1997 to 2000.

Legislation

- SB 318, Thompson, chaptered October 7, 1997, acknowledged the need for more time to allow development of straw-using businesses and to financially assist the process.
  - SB 318 paused the burning phase down schedule for three years by allowing burning of up to 90,000 acres in the fall and 110,000 acres in the spring for the years 1998-2000. It exempted up to 2000 acres for administrative burning.
  - SB 318 changed the conditional burn clause in AB 1378, the original legislation that began the phasedown, so that burning for disease control can occur during the same year that the disease is determined to cause a yield reduction. SB 318 maintained the prohibition on transfer, trading or selling of conditional burn rights. To obtain a conditional burn permit, fields must be inspected and determined to have a disease sufficiently high that it will cause an economic loss. A separate committee developed recommendations to implement the conditional burn clause. The Alternatives Committee extensively discussed the difficulties of the conditional burn clause and recognized it is troublesome to administer and apply. Changing the law to allow trading of burn rights (which is not permitted after full phasedown) was recommended in the last Alternatives Advisory Committee Report because it could more effectively allocate available burn acreage without so much administrative overhead. The intent was to enable those who need to burn most to acquire acreage from those who don't need to, so that burning would be allocated where it was most

needed. Trading assumes that every grower initially has entitlement to burnable acreage. Such entitlement has not been established and would depend on appropriate survey work to determine the average level of disease in Sacramento Valley rice fields. The conditional burn clause requires fields be verified as having disease and the permission to burn will be associated with that field only. For this situation to change, the underlying philosophy of the law would have to change to provide every grower a pool of burnable acreage for disease control reasons. To do this would recognize that some aggregate level of disease exists which would support conditional burn status.

- SB 318 also established the Rice Straw Demonstration Project Fund (Rice Fund) a grant program to demonstrate new rice straw technologies. Three Rice Fund grants were awarded in 1998 for a total of $2.07 million, four in 1999 for $2.2 million and five in 2000 for $1.23 million. Businesses receiving these grants demonstrated a degree of economic and technical feasibility that made them candidates for commercial viability. The grant helps their progress but does not guarantee success. However, the committee feels the Rice Fund grants should improve the chances of success of emerging rice straw businesses. The grantees included:

  1998 Project Grants

  Anderson Hay & Grain Co., Inc. $500,000, *"Preprocessing of Rice Straw for Multiple Products."* Initial estimate of annual straw use after five years: 205,000 tons.

  FiberTech USA, Inc., $750,000, *"Bioboard Plant for Colusa, California."* Initial estimate of annual straw use after five years: 25,000 and 40,000 tons.

  MBI International, $820,000, "*Production of Fermented Animal Feeds from Sacramento Valley Rice Straw: Prototype and Commercial Pilot."* Initial estimate of annual straw use after five years: 160,000 to 330,000 tons.

  1999 Project Grants

  Agriboard Industries L.C., $665,000*, "Phase One Development of the Agriboard Industries L.C. Rice Fiber Based Structural Panel Plant in Sacramento Valley, California*". Initial estimate of annual straw use after five years: 46,000 tons. **Project withdrawn**.

  Louisiana-Pacific Corporation, $565,753, "*Medium Density Fiberboard Manufactured from Sacramento Valley Rice Straw Residuals*." Initial estimate of annual straw use after five years: 70,000 tons. **Project withdrawn**.

  Enviro Board Corporation, Inc., $500,000, "*Colusa Rice Straw Project*." Initial estimate of annual straw use after five years: 80,000 tons.

Arkenol Holdings, L.L.C., $519,247, *"Production of Citric Acid From Sacramento Valley Rice Straw."* Initial estimate of annual straw use after five years: 160,000 tons.

2000 Project Grants

Funds from withdrawn projects allowed funding of:

Rice Straw Cooperative, $380,000. "*Evaluation and Delivery of Rice Straw Needed for Gridley Ethanol Plant's Startup Year of Operation*." Initial estimate of annual straw use after five years: 75,000 to 300,000 tons.

Broken Box Ranch, $297,589. "*Development of a Commercial Scale Composting Plant in Colusa County*." Initial estimate of annual straw use after five years: 50,000 tons.

Kuhn Hay, a California Corporation, $402,311. "*Rice Straw Export Project*." Initial estimate of annual straw use after five years: 100,000 tons.

Smith Ranches. $50,100*. Rice Straw Silage Production for Cattle Feed*. Annual straw use after five years: 20,000 tons.

Arkenol Holdings, L.L.C., $100,000. "*Production of Ethanol From Rice Straw*." Initial estimate of annual straw use after five years: 264,000 tons.

See the Rice Fund website for details and progress reports:

http://www.arb.ca.gov/smp/rice/ricefund/ricefund.htm

- The California Legislature adopted resolution, AJR-4 (Maldonado) in 1999 to encourage the use of "weed-free straw or California- grown rice straw" for erosion control and road construction. The resolution originated from California cattlemen who were concerned about invasive and non-native plant species damaging rangeland. Yellowstar thistle has invaded over 20 million acres of rangeland in California, up from 1.2 million in 1965. This resolution would help increase confidence in use of rice straw for erosion control because the weeds of rice nearly all require an aquatic environment and would not succeed in an upland environment. Those that are not strict aquatics, particularly *Echinochloa crus-galli* (barnyardgrass, annual), are already widespread in California. However, one species, *Lythrum hyssopifolia* (grasspoly, annual), is in the same genus as *L. salicaria* (purple loosestrife, perennial) and raised some concern. Grasspoly is currently widespread and can infest pastures. Purple loosestrife, the target of several weed management districts, is a troublesome weed in moist soils, including pastures, but is not known to infest rice fields. A Weedfree Forage Sub-committee of the Weed and Vertebrate Pest Committee, composed of Agricultural Commissioners, federal and state agency

staff, growers, harvesters, and product users is studying whether these rice weeds pose a risk if straw is used in non-rice environments.

- A Conditional Burn Committee was appointed in 1997, and in 2000 released its recommendations for implementing the conditional burn provisions of AB 1378. Its recommendations were published in “Proposed Regulations for the Conditional Rice Straw Burning Program–Staff Report, September 2000," and adopted by the Air Resources Board on September 28, 2000. The regulations provide the framework for evaluating fields for disease, training inspectors, and reporting and interpreting results of field inspections. After September 1, 2001, the permit to burn Sacramento Valley rice fields is conditioned on the presence of an economically damaging level of disease. Features of the regulation include qualifying diseases (stem rot, aggregate sheath spot, blast), field inspection, training and reporting protocols, and oversight by the county Agriculture Departments. The Sacramento Valley Basinwide Control Council (BCC) submitted a program in accordance with ARB's regulation. The BCC is also required to report on the program's implementation and submit program amendments as necessary. The existing program may be amended after June 1, 2003 if the BCC chooses to propose alternative methods of quantifying disease. This includes the possibility of allocating a base level of burnable acreage to every grower without the need to quantify disease in each field.
- SB 1186 chaptered in February 1999, requires the ARB to submit recommendations for ensuring consistency and predictability in the supply of rice straw for cost-effective uses, including, but not limited to, recommendations for methods of harvesting, storing and distributing rice straw for off-field uses. This report, due to the Legislature on January 1, 2001, was done in cooperation with CDFA, the California Energy Commission (CEC), and the California Integrated Waste Management Board (CIWMB). The report makes several recommendations, including Legislative action on research to improve straw harvesting, handling, transportation and storage; increase funding to the Rice Fund; extend the end users tax credit program to 2015; and provide fiscal measures to offset the cost of harvesting, handling, transportation, and storage of rice straw.

Rice Straw Facilities

- Only one new processing plant, FiberTech, has come on line. In fall 1999, they stockpiled a large quantity of straw and are the primary reason the baling increased to approximately 4% in that year. Since this is the first commercial facility that can potentially use large quantities of straw, the industry is closely watching progress as this plant scales up their production.
- Phaseout of MTBE in reformulated gasoline products should stimulate interest in use of ethanol as both an oxygenate and an octane booster. At the same time, this could

provide a stimulus to job-short rural counties, according to the Rice Promotion Board staff (Herkert, 1999) and a draft report from the CEC (Publication 50-99-011). The Rice Promotion Board stated that, compared to other alternatives, "conversion of straw to ethanol is the most technically feasible and economically viable method of converting millions of tons of waste into something valuable and environmentally friendly." This could boost processes that will make ethanol from agricultural products. The planned BCI-Gridley LLC Ethanol Facility, "is about to begin final stages leading to the construction of an ethanol generating facility near the town of Oroville (Herkert, 1999)." As of September 2001, it is estimated that at full capacity the plant will use 350,000-400,000 tons of rice straw and produce 23,000,000 gallons of ethanol annually. An estimated 10 mW of electricity for delivery to the California power grid will also be generated. Renewal of interest in ethanol as a fuel additive could also stimulate revival of an earlier project involving Arkenol Holdings in north Sacramento County. That project proposed using acid hydrolysis to pre-process straw and is similar to the method it plans to use for citric acid. ARB (Hrynchuk, 1998) estimates that up to 200,000 tons of rice straw per year could be diverted to ethanol if one plant were built.

Executive Order D-5-99 calls for the phase out of MTBE and directs the CEC to evaluate the potential for ethanol production in California and to examine the environmental and technological consequences and constraints of using ethanol. The CEC report states that biomass has potential to meet state needs for oxygenated fuel (as high as 1.1 billion gallons/year if ethanol replaced MTBE), but the cost is high and would require government support to make it competitive. Concerns were also raised about commercializing unproven technologies. Commercialization, which is considered high risk, is currently limited by access to capital and reliability of low-cost, consistent quality feedstock. The report suggests that the state co-fund the first few production facilities as demonstration projects and that "a clear integrated statewide biomass-to-ethanol fuel policy to support ethanol fuel production and use" is needed.

Recommendation: *Encourage the State of California to support use of ethanol derived from agricultural waste as a fuel and fuel oxygenate to replace MTBE, and for other uses, if environmental, technical, and economic studies are supportive.*

- The *Rice Straw Diversion Plan* (Hrynchuk, 1998), noted the impossibility of utilizing 50% of the straw by 2000, as called for in SB 318, and identified an alternative plan. Without intervention, the use of rice straw is expected to rise from about 3% in 2000 to only 23% in 2003, primarily through growth in livestock use and to a lesser extent in manufacturing and environmental uses. No near-term large energy use was envisioned, although the phaseout of MTBE and U.S. EPA's denial of California's

oxygenate requirement waiver request may change this view. If several proposed intervention measures were adopted by January 1, 2000, ARB staff believed there was a possibility of achieving the 50% usage target by 2003. Possible interventions include studies on several aspects of straw infrastructure (supply, costs, quality specifications, etc.); incentives for end-users in the form of loan guarantees, low-interest loans, accelerated capital depreciation, or grants; support for research; encouragement of state agencies to use rice straw; and modification and increase of the tax credit program. The report also includes a brief analysis of the status of several straw processes and gives projections on their annual capacity. The Committee supports consideration of most of the measures outlined in the *Rice Straw Diversion Plan*. Those measures from the *Diversion Plan* that are not separately made elsewhere in this report are listed below:

Recommendation: *The Committee supports consideration of several government intervention or industry-supported measures suggested by the Rice Straw Diversion Plan:*

- *Conduct or support studies on straw supply potential, current supply of straw, options and costs of methods and equipment, storage, transportation, standards and grades*
- *Conduct or support studies on potential for secondary straw market such as compost and anaerobic digestion*
- *Provide information and administrative assistance to develop straw cooperatives and straw distribution and marketing centers*
- *Provide financial resources for end-user businesses, such as 30% loan guarantees, low interest loans, accelerated capital depreciation, or 50% matching grants*
- *Provide financial resources for research projects to address technical barriers so that results are in the public domain*
- *Provide resources to develop a Rice Straw Business Assistance Program to help new business access financial and educational assistance*
- *Encourage state agencies to use and promote rice straw products where such use would be appropriate*

Rice Straw Tax Credit Program

- The Rice Straw Utilization Tax Credit Program (SB 38, Lockyer, 1996) issued tax credits to end users of rice straw for $90,509 (6,034 tons) from the 1997 crop, $246,715 (16,448 tons) from the 1998 crop, and $384,319 (25,621 tons) from the

1999 crop. End users have been primarily dairy and cattle operations for animal bedding and feed use. Particleboard manufacturing was responsible for the increase from 1998 to 1999. Additional end uses have included compost, bale construction and erosion control. After two years of experience several possible changes in the legislation for this program were discussed in the 1998 tax credit program report which, in the Committee's view, would provide a considerable incentive for increased straw utilization. The measures include larger and more diverse projects, improving equity (change the first-come, first-serve rule), allow selling tax credits to encourage out-of-state investment in rice straw business, and allowing use of unused tax credit funds for other straw utilization purposes. The Committee supports these suggestions. The Committee did not support capping the individual tax credits at $1,000 to $4,000 because it will limit the value of the program to smaller users. In addition, the Committee would like to see "forward contracting" under the tax credit program so that potential users would know ahead of time if they will get the tax credit. This change would require changes in either the cap or eliminating the first-come, first-serve rule. For details see *Report to the Legislature, Rice Straw Utilization Tax Credit Program,* California Department of Food and Agriculture, June 1, 1999

Recommendation: *Expand the Rice Straw Utilization Tax Credit Program by lifting the annual $400,000 cap to attract larger and more diverse projects; allow trading of tax credits so users of rice straw with no California tax liability will be encouraged to invest; dedicate the unused tax credit each year to other activities to support utilization; allow 'forward contracting' of rice straw under the program so that users will know if they are eligible for the tax credit prior to harvesting the straw. Allow growers to use their own straw and take the tax credit.*

AB 2514, Agricultural Biomass Utilization Account

- This bill was chaptered September 30, 2000 and funded for $2 million. It provides a per ton grant for end users of agricultural biomass for processing, generating energy, manufacturing, exporting, preventing erosion or any other environmentally sound purpose. Open field burning is excluded. CDFA administers the grant in consultation with ARB and the CIWMB.

Rice Straw Research

- A USDA funded research project, *Rice Straw Harvesting and Handling for Off-Field Utilization*, Bakker-Dhaliwal, et.al., UC Davis, issued its first report in July, 1998, and the second report in Nov. 1999. The project is conducting time and motion studies

on rice straw handling, evaluating equipment, doing cost assessments and developing a GPS model to guide plant siting and transportation routing. This is a primary information source for industry. Among the findings in the 1998 report are preliminary system cost analysis, showing costs in the range of $15.24 to $30.87/ton for small bales and $10.84 to $15.36/ton for large bales, for harvesting, baling and roadsiding. The 1999 report gives a more detailed analysis of each component in the gathering and transporting process. In a more recent report (Jenkins, et.al, 2001), additional straw removal costs included loss of nutrients, cost of purchasing straw, additional handling at the user site, cost of effects on plant operation due to quality differences, and cost of waste handling. Potential cost reduction might accrue from reduction in diseases when straw is removed. His data suggest that increasing straw yield per acre reduces cost per ton and that "larger scale harvesting can lead to economies of scale". However, the need for specialized equipment may increase cost. Jenkins, 2001 identified several incentives for harvesting straw, including growers subsidizing the cost of removal; tax credits to purchasers of rice straw; grants to end users; biomass to energy incentive grants; and emission offset credits.

- In a report dealing with the engineering aspects of rice straw harvesting and handling, Summers, et.al. 2001, noted that straw yield ranged from 3.3 to 5.2 ton/ac, depending on variety and location. Cutting height also had a dramatic effect on straw yield, reducing yield 30 to 50% when straw was cut at the water line. Silica was found to be concentrated in the leaves instead of the stems, leading to speculation that harvesting methodology might separate these fractions to the benefit of end users. Studies on degradation of straw during one year of storage showed nil losses in pole barns and indoor storage compared to 18% loss for tarp storage and over 50% for exposed storage. In the tarp study, a leak allowed some rain exposure. Summers reported self-heating of bales as a function of moisture and microbial activity. In single exposed bales, temperature rose after rainfall events to a maximum of 62^{o}C, peaking after seven days, then diminishing.
- Additional straw utilization research included:
  - A feeding trial at the Imperial Valley Research and Extension Center (Zinn, 1998) found that macerating rice straw improves its feeding value when used at 15-20% of a complete diet for growing-finishing feedlot cattle.
  - A Sacramento Valley preliminary trial (Nader, 1998 and 1999) successfully ensiled rice straw for subsequent cattle feed use. Follow-up work in 1999 confirmed that freshly harvested, high moisture rice straw could be ensiled (in bags) and that cattle would readily eat it. Feeding studies are planned for winter of 2000. Related studies tracked the change over time after harvest in feed value of straw and identified preferred varieties for feed use.

- A survey of pesticide labels (Dye, 1999) identified which rice pesticide products have label statements relating to use of straw for livestock feed, forage or bedding. This was done to assist label compliance and create confidence in California rice straw as a safe livestock feed product. Most rice pesticides registered in California do not have such statements that restrict the use of straw. Several materials have specific waiting times after application before livestock can use the straw but they are short enough they would not ordinarily pose a constraint on use of straw. Two herbicides (Prowl and Whip) prohibit use of straw for livestock feed, forage or bedding. Several glyphosate (Roundup) products have an eight-week waiting period following treatment but do not prohibit use of straw for feed or bedding.
- Other ongoing research includes studies on the recycling of nitrogen, evolution of gases from decomposing rice straw, and changes in disease, insect, and weed population and damage (Agronomy Progress Report, No. 264, June, 1999). One project, funded by the CDFA Fertilizer Research and Education Program, is evaluating the effect of straw removal on nitrogen and potassium (K) nutrition in a low K soil. Previous work suggests that some soils may encounter K deficiency when straw is baled and removed.
- In a report of long-term rice straw incorporation, Van Kessel and Horwath (Feb., 2000) stated that after six years of incorporation, rice yields were not decreased when recommended rates of fertilizer nitrogen were used and incorporation reduced nitrogen (N) fertilizer input by approximately 25 lbs. N/ac. However, they also expressed concern that incorporation may limit maximum yield potential as N rates are increased compared to burning. They suggest this limitation is related to disease and weed pressure, which increased in the incorporated plots, particularly as N rates increase. Additional work at higher N rates is needed to determine if maximum yield potential is limited by incorporation.
- Webster and Cintas, 2001, confirmed, in a multiyear study, that increasing stem rot severity is linearly related to yield reduction; that annual burning was most effective at reducing stem rot sclerotium compared to incorporating, rolling or removal; and that winter flooding was equal to burning in reducing stem rot severity compared to non-flooding, across all management methods.
- Hair, 2001, found that “watergrass densities recorded in the straw incorporated plots were, on average, about 1,000 times the density of watergrass in the burned plots.” He related this effect to seed survival during the winter because incorporation stores the seeds in a ‘seed bank’ preventing exposure to depredation by bird predators. In addition, seeds left on the surface may be subject to enhanced germination and subsequent killing when fields are tilled in the spring.

- Godfrey, 2001, found that rice water weevil populations were greater in the non-flooded straw treatments compared to the winter flooded treatments. The difference was economical, but the reason for the difference is not yet known. Other invertebrates, such as tadpole shrimp, crayfish and seed midge were not affected by straw treatments.

Rice Straw Baling

- Rice straw baling activity remained small in scale but appeared to increase in 1997 and 1998 compared to previous years; however, there is no rice straw utilization reporting mechanism that gives accurate amounts. Estimates of baling varied widely depending on the source, including 30-40,000 tons on roughly 13,000 acres (Bakker-Dhaliwal, 1998), 13,439 tons in 1997 (Hrynchuk, 1998), and 20,000 tons in 1998 (CDFA, Report to the Legislature, 1999). For the 1998 season, the Committee requested that County Agriculture Department offices in the Sacramento Valley collect information from growers on what they did with their rice straw as they got their pesticide permits. All rice counties except Sacramento and Tehama reported. In addition, the effort began after the permit process was underway, so some straw baling was probably missed. Total acres reported baled for the Sacramento Valley for 1998 straw was 7514 plus/minus 50 acres (given below), or about 1.6% of the total planted. This equates to roughly 15,028 tons of straw.

County	Colusa	Glenn	Butte	Yolo	Sutter	Placer	Yuba	Total
Acres	2,475	925	1,385	1,610	853	158	107	7,514

Several activities influenced the use of straw:

- Rice Fund grants and similar promotional activities such as the High Sierra Resource Conservation & Development Area Rice Straw Utilization Project for Placer and Yuba Counties.
- Rice straw usage by livestock fluctuated, depending on weather patterns that affected the supply of traditional feed. Usage by livestock was higher in 1997 than in 1998.
- A grower straw baling cooperative formed near Gridley, originally to supply the anticipated ethanol plant, and baled 2200 tons from 1189 acres. The straw, baled by Anderson Hay and Grain, totaled 2500 tons in 1998.
- Industry groups, such as the California Rice Industry Association, the former California Rice Promotion Board, and the Rice Producers of California actively sought support for the utilization of rice straw in the

legislature and promoted development of emerging businesses by conducting tours, providing samples and giving testimony.

- Numerous bale construction projects using rice straw were undertaken. This sector has the highest profile but is currently a low volume user. Input to the Committee (Hardwick, 1998) suggested that an impediment is the wide range of local jurisdictions reacting in various ways to the Health and Safety Code which permits straw bale construction in California. There is uncertainty in the permit/loan/insurance process. In addition, it was suggested that completion of various testing procedures for certification of rice straw would increase demand. The primary areas where testing is needed include structural (particularly seismic), fire rating, and insulation value. Completion of these tests would help increase confidence in rice straw as a building material across the state. In addition, the industry needs to endorse a common set of parameters that describe "construction grade" rice straw bales for use by designers and builders so they will understand the properties of rice straw bales and have a consistent product.

Recommendation: *California Dept. of Housing and Community Development undertake and complete seismic, structural, fire, and insulation tests of rice straw bales intended for construction purposes and incorporate the results in the Uniform Building Code of California. Standards for 'construction grade' rice straw bales should be developed and adopted by industry.*

Rice Straw Management Practices

- Rice growers continue to rely on soil incorporation as their primary method of rice straw management. Most growers have adopted methods that best suit their equipment, labor supply, time line and other needs, and have integrated straw management into their cropping system. They are constantly refining their methods as new equipment and ideas emerge.
- Compared to 1994-96, when 41-57% of the acreage was burned, 1997 and 1998 burning was very limited. Fall burning particularly was lower, reduced in 1997 by weather and in 1998 by a combination of SB 318 limits and climatology. This change in permitted fall burning has had the effect of reducing total burning. Many growers found spring burning was impractical and chose to soil incorporate what they could not burn in the fall. In 1998, the first year of the SB318 limits, nearly 100% of the allowable fall burning was utilized but only 47% of the allowable spring burning was used. Some growers traded for the right to burn extra acreage where

disease management or other considerations made it desirable for them to burn. Actual burned acreage in 1994-98 is given in Table 1.

Table 1. Fall and Spring Rice Straw Burning, 1997-98.

Crop Year	Planted Acres	Fall Burn	Spring Burn	Total	% Burned
1998	490,625	69,284	64,356	140,627	28.7
1997	517,233	89,418	51,209	133,640	25.8
1996	514,720	109,077	102,245	211,322	41.0
1995	500,705	75,384	192,832	268,216	53.6
1994	514,045	102,498	190712	293,210	57.0

Source: CARB, 2000.

- Winter flooding is the most popular and effective method of straw incorporation and draws favorable attention to the rice industry by increasing winter wetland habitat for migrating waterfowl. Ducks Unlimited (Annual Report, 1998-99) interviewed 200 rice growers who planted 202,443 acres of rice in 1998. This was 41% of planted acres in the Sacramento Valley. Of the surveyed acreage, 57.7% was winter flooded. Similar data for 1997 and 1996 were 55.3% and 50.4%, respectively. While this report did not claim to be representative of the whole Valley, it includes a sufficient amount of acreage to suggest that winter flooding is the most commonly used method, is growing in use, and may include up to half the planted acreage.
- Reliable data is available for planted acreage and burning but not for incorporation and utilization. Extrapolation from various sources was used to construct the following table summarizing rice straw disposal alternatives.

Table 2. Estimated Acreage of Different Rice Straw Management Practices

(1997 and 1998 crop)

Management Method	1997	1998
	Acres (%)	
Burned[1]	135,640 (26.1)	140,627 (27.4)
Incorporated[2]	372,474 (71.9)	338,900 (70.6)
Winter flooded	282,030 (54.4)	281,760 (58.7)
Rainfed	90,464 (17.5)	57,140 (11.9)
Baled and utilized[3]	10,360 (2.0)	9,600 (2.0)
Total planted acres[4]	518,000	480,000

[1] Burn data provided by CARB

[2] Total incorporation based on difference of total planted less burned plus baled. Winter flooded data extrapolated from Ducks Unlimited, "Rice Enhancement Project" Annual Report: 1998-1999, Feb. 28, 1999.

[3] Baled estimate of 2% of the acreage.

[4] Planted acres from "California Field Crop Review," April 16, 1999, California Agricultural Statistics Service.

- The primary industry concern related to rice straw is the high cost of straw management. Coupled with low yield in 1995, 1996, 1998 and 1999, Sacramento Valley rice growers are in a cost/income squeeze. Growers report they are operating at break-even income levels because of rising costs, lower yields, and the low price of rice. The added cost of incorporation is burdensome compared to burning. As one grower commented at the June 30, 1999 ARB stakeholders workshop in Colusa, making the reduction from 40% burning permitted by SB 318 to no burning "is an economic leap and may put me out of business." The dollar cost of soil incorporation varies widely depending on the system and overhead costs, but averaged $35/ac in one study (Williams, 1998), and $43/ac in a recent cost analysis (Williams, 2001).
- Significant additional effects from changes in straw management include impacts on weeds, fertilizer, diseases, winter water use, local flooding, and wildlife. They appear to be a mix of both positive and negative impacts.

- In California field research, a 1000-fold increase in watergrass panicle density was observed in incorporated plots compared to those that were not incorporated (Hair, 1999 and 2001). Some growers have more weeds in incorporated fields and report spending more on weed control.
- Research reported by Horwath, (1999, 2001) "clearly shows the value of residue incorporation in increasing soil nitrogen availability and that fertilizer applications could be reduced."
- The relationship of straw incorporation to stem rot disease has been discussed in previous reports. A new concern growers have is the effect of straw management on blast disease. Blast overwinters in straw residue and burning will reduce the overwintering inoculum in the straw. However, blast spores can blow on the wind from infected adjacent fields during the summer growing season, so burned fields can still get blast. Research has not established whether or not burning blast affected fields will result in reduction of blast the following season. Blast is one of the qualifying diseases in the conditional burn permit program.
- Winter water use for flooding increases overwintering habitat for waterfowl, but in drier years could compete with water needs for anadromous fish and for salinity control in the Delta.
- During wet years, the expanse of flooded rice fields may increase runoff and add to local flooding problems.
- Elphick and Oring, 1998, concluded that "flooding rice fields increased suitable habitat for most, but not all, species (of waterfowl) studied." Twenty-four of thirty-one species were more common in flooded rice fields. Only great blue herons and sandhill cranes were more common in unflooded fields.

- Given the mix of potentially beneficial and detrimental impacts of various rice straw management methods, the Committee discussed the advisability of any rice straw management system that is completely dependent on one method only. Each system has advantages and disadvantages. For example, burning is good from the growers' perspective for straw removal, is low cost and helps with disease management, but is not acceptable by the general public and is not the best situation for most waterfowl. Winter flooding helps the waterfowl, but competes with other water users. Off-field utilization is beneficial for removing straw and provides the opportunity for new and valuable products, but takes away nutrients and organic matter. The Committee concluded that a mix of systems will help offset the disadvantages associated with reliance on a single system. For example, burning tends to volatilize nitrogen while incorporation preserves it for use by the crop. The same comparison is true of utilization and incorporation. Conversely, incorporation tends to maximize disease inoculum while burning or removal can help reduce

inoculum. From another perspective, a mix of systems will benefit different species of waterfowl and upland birds, depending on their preferred habitat. Hence, one system can help offset the deficiencies of another, leading to the conclusion that rotation of straw management systems, including burning, incorporation and removal should help sustain a healthy soil environment for rice and benefit wildlife. The Committee believes that a mix of methods is the ultimate Best Management Practice. The exact mix of methods is dependent on many factors, including the problems with one system that another may help solve. The particular mix of methods will no doubt vary among growers and will suit their unique circumstances. This concept has implications for growers and policy makers. For growers, the concept of a straw management rotational system will provide the best blend of practices to ensure long-term sustainability. For policy makers, acknowledgment of the need for a mix of straw management methods will help in making future decisions about limitations on burning and influence the goals about utilization.

Recommendation: *A long-term straw management goal to enhance the sustainability of rice production is the recognition by all stakeholders, including growers, end-users and public agencies, that complete reliance on a single system of rice straw management is undesirable and that a blend of straw management alternatives should remain available, including incorporation, baling and removal, and burning, which can be used in a rotational sequence.*

Summary

The 1997 Committee report made several recommendations, including roles for government, such as direct subsidies (tax credits and/or loan guarantees) and assistance in developing straw businesses. These recommendations have been partially addressed by enactment of the tax credit and the Rice Fund programs. Similarly, recommendations related to research on utilization, infrastructure, and in-field management are also being addressed. Recommendations that have not been addressed include government support of rice straw ethanol for energy, standards for straw bale construction, research on rotation crops to provide additional straw disposal approaches, and an amendment to AB 1378 to allow permit trading under the conditional burn section. A final recommendation in the 1997 Committee report dealt with cooperative efforts to stabilize supply, meet straw demand, optimize government use of rice straw, and establish a rice straw storage budget for the California Department of Forestry. These have not been accomplished and most are revised in the next section of this report.

THE STATUS OF RICE STRAW MARKETING INFRASTRUCTURE IN CALIFORNIA: HARVESTING, HANDLING AND STORAGE

The 1997 report of the Advisory Committee on Alternatives to Rice Straw Burning cited the vital role of rice straw harvesting, handling, and storage in the viability of any process that uses rice straw. It noted that in the absence of an efficient straw marketing infrastructure, utilization of rice straw would be severely constrained. Previous reports have recommended actions to enhance the economic feasibility for selected startup companies via grant funds and tax credits for end users. In the two years since that report was issued, attention of industry, research and the Committee has focused on several elements of a straw marketing infrastructure. 'Infrastructure' includes gathering, transporting, storing and preparing straw for subsequent utilization in a number of products and processes. This discussion examines the status of the infrastructure, identifies some barriers and concludes with recommendations to help mitigate those constraints. It begins with an examination of some fundamentals about rice straw--when and how much straw is available--and is followed by a discussion of several issues relating to harvesting, handling, storage and marketing.

Time of Straw Harvest and Quantity of Straw Available

Two fundamental issues of rice straw are the time of year when the straw is harvested and available, and the amount available for utilization.

Time of Straw Harvest

The time when rice straw is available for harvest has significant impact on operation of the rice straw marketing infrastructure. Like grain and other dry commodities, straw is a seasonal commodity that can be stored for the balance of the year. Rice straw is generally available for baling during a two to three month period, primarily September, October, and into November. Straw harvest begins immediately after grain harvest and ends with the first heavy rains. In 1997, rice straw harvest began the last week of August and continued until the end of November. Peak harvest times were from mid-September until Mid-November (Jenkins, et.al. 1998). Several factors determine the time when straw is available for harvest.

- *Weather*. Dry weather and dry straw are needed for nearly all successful rice straw gathering efforts, although high moisture straw (60-70%) is needed for silage, currently under experimental development. Most processes, including feed, require straw at a moisture content below 15%, which is necessary to retard mold. Rice straw dries rapidly following harvest with a cutter-bar type harvester that cuts and partially shreds the straw. Depending on weather, straw that is spread in the field

will dry to a suitable moisture for baling within a day or two of grain harvest. Hence, for most uses, straw harvest may begin shortly after grain harvest. The straw of rice which has been harvested with a stripper header remains attached to the soil and stays green because it is still a living plant, so must be cut with a mower or swather before it can be baled. Frost and dry soil will also kill living rice stubble. Straw harvest effectively ends with continued rain in the late fall and early winter. Spring baled straw is not acceptable for most purposes and is difficult to bale and may have more dirt and green weeds in it. A possible exception is use of spring baled straw as a component of a wood/straw fuel mix in biomass power plants. Spring straw has lower potassium and chlorine that cause fouling of heat exchange elements of the burner.

- *Field conditions*. Soil moisture content is crucially important for timing straw harvest to enable swathing, baling and loading equipment to operate, to dry the straw, and prevent dirt from getting in the bale. Sometimes, fields get rutted from weed sprayers and grain harvest equipment that may prevent straw harvest. Rainfall during the harvest season may require straw rows be turned to dry the bottom side.
- *End-use*. The end use of the straw will affect when it is baled. Some uses are highly specific, such as silage which must be gathered right behind the combine, and rice 'hay' which must be baled a day or two after grain harvest; however, direct combustion of straw for power generation requires spring-baled straw. End-uses will have quality specifications associated with them that will affect harvest time.

Quantity of Straw Available.

Companies investing in rice straw utilization need to know how much is available. The above ground portion of the rice plant represents the potential straw yield and is the amount that farmers must incorporate or burn. However, the potential yield may not equal the actual or recoverable yield associated with a given harvest method or use. Recoverable yield is primarily a function of the straw gathering process, not the farming process. Limitations on recoverable straw yield are discussed below.

- *Potential yield*. The biological yield of rice straw varies by location, variety and crop nutrition. Recent studies (Summers, et.al., 2001) give a range of 3.34 to 5.18 tons/ac, oven dry basis, under commercial growing conditions, depending on variety and location. This represents the total above ground straw without the grain. This biological measure of straw represents the 'potential' yield. Roberts, et.al., 1993, reported that the straw yield of optimally fertilized semidwarf rice varies in the range of 2.25 to 4.5 tons/ac., based on optimum response to fertilizer nitrogen. The mean straw yield, at predicted maximum grain yield, was 3.76 tons/ac for tall varieties and 3.56 lbs./ac of straw for semidwarf varieties, a difference of 5%. Fertilizer nitrogen rates were very important in determining straw yield. Semidwarf varieties produced less straw than tall varieties at all nitrogen (N) rates, but straw yield of both types

increased with increasing N. Predicted maximum straw yield for semidwarf varieties was 3.81 tons/ac at 216 lbs. N/ac, and 4.58 tons/ac at 245 lbs. N/ac for tall varieties. These N rates are well above what growers would normally use. The California rice industry grows primarily semidwarf varieties.

- *Recoverable yield*. In 1997, Jenkins, et.al., studied commercial rice baling operations on 939 acres and calculated an average yield of 2.3 tons/ac (2.0 dry tons/ac). Anderson Hay and Grain reported an average yield of 2 tons/acre in 1998 when cutting at the water line, or about 4-6" off the ground. Ken Collins, in an oral report to the Committee, reported a yield of 1.85 tons/ac in 1998. Other reports from industry, dating back to 1996, suggest yields in the 2 ton/ac range (J. Williams, pers. comm.). What factors explain the difference between potential and recoverable rice straw yield?
    - *Weather*. Climate can affect straw yield by its impact on growth and by its effect on the ability to collect the straw. Straw growth related to climate has not been studied in California and we do not know the amount of annual variation. However, the experience of 1998, the 'El Nino' year, suggests that late planting and a shortened growing season can reduce the amount of straw available, primarily by reduced tillering. Inclement weather--rain, dew, fog--can dramatically affect equipment operation and field condition and reduce the amount of straw recoverable. Adaptations to wet and rutted conditions that are used on rice grain harvesting equipment, such as wide tracks, high flotation tires and four-wheel drive might eventually be adapted to straw harvesting equipment. However, even with these adaptations, rice straw moisture will still be an obstacle that limits the straw yield.
    - *End-use*. There is much to learn about the specific requirements for end uses of rice straw, but it is clear industry will categorize straw properties according to their needs, and this will affect the 'recoverable' yield. Some uses, for example ethanol production, press board, composites, bale construction, some feed uses, etc.--may be able to use the entire above ground portion of the plant, so the supply of straw for them will be higher, and close to the 'potential'. However, other end users may want only the portion of the plant above the waterline. In this case, 'recoverable' yield will be somewhat lower than 'potential.'
    - *Method of harvest.* Height of cut is one of the most important determinants of yield. In the studies which determined potential yield (Roberts, 1993; Summers, et.al, 2001), the straw was cut as low to the ground as the harvester could go, usually leaving 1-3" of stubble. However, Anderson Hay and Grain reports that the ideal stubble level appears to be 4-6" above the ground, to minimize dirt in the straw and minimize phytosanitary concerns for exported straw.

Growers usually plan to bale before they harvest the grain, so they can coordinate their grain harvest with the straw operations. For example, they may cut the straw at water line and leave it in a windrow, instead of spreading, which the baler can directly bale. In this case, they will not use a swather but windrows may require turning with a rake to dry them. More commonly, growers cut above the waterline and spread the straw, and a swather cuts to the waterline, followed by a rake to make windrows. If the rice is lodged the grower must harvest grain at ground level, resulting in higher yield.

Stripper harvesters leave the entire rice stalk attached to the ground. Baling such fields requires swathing, usually at the waterline. Tracks left by stripper harvesting presses 25-30% of the standing straw onto the ground, making it hard to cut by the swather, which reduces yield.

- *Baling costs and incentives.* The party who bears the cost of baling has an incentive to control costs and this can impact straw yield. For example, balers may take only the loose straw and leave the stubble because it is cheaper than total harvest. This method may remove sufficient straw to satisfy the grower's straw disposal goal, although it will not be helpful for stemrot management. If end users want higher yields, they will need to spend more by swathing or arrange with the grower to cut the straw closer to the ground when harvesting grain.

- *Straw supply*. The *Rice Straw Diversion Plan* estimates that 45 to 50% of rice straw may <u>not</u> be available for use. The actual amount available for use will vary annually depending on the factors discussed above and the willingness of growers to bale their straw compared to what they are currently doing. There is an economic incentive for baling if the cost to the grower is lower than their current method of disposal. Baling may also be the choice if the grower perceives that straw incorporation is reducing yield, increasing disease or weeds, or is otherwise undesirable. Baling is a disincentive if the cost is higher or loss of nutrients and organic matter is a concern to the grower. It is likely that some growers will not want to bale their straw because they see it as a resource or are happy with what they are currently doing. It is unknown how many growers will prefer to adopt either option. A range of straw supply values for two yield levels is given in the following table, assuming 500,000 planted acres, which has been typical for the past several years. The table includes harvest acreage up to 50% because the committee believes that it is unlikely, given the various constraints to baling, that it will exceed 50% in a given year.

Table 3. Estimated Straw Supply at Two Straw Yields and a Range of Baled Acreage.

(Assumes 500,000 acres planted)

Acres harvested	Straw Supply @	
	2 tons/ac	3 tons/ac
%	total tons	
20	200,000	300,000
30	300,000	450,000
40	400,000	600,000
50	500,000	750,000

The draft ARB report *Recommendations for Ensuring the Consistency and Predictability in the Supply of Rice Straw for Cost-Effective Uses*, Feb. 2001, makes several recommendations, including Legislative action on research to improve straw harvesting, handling, transportation and storage; increasing funding to the Rice Fund; extending the end users tax credit program to 2015; and implementing fiscal measures to offset the cost of harvesting, handling, transportation and storage of rice straw.

Recommendation: *Users of rice straw should be aware that supplies vary on an annual basis and are encouraged to project their needs over several years and plan a prudent reserve*. *The Committee supports the recommendations of the draft report "Recommendations for Ensuring the Consistency and Predictability in the Supply of Rice Straw for Cost-Effective Uses" cited above. See the report located at http://www.arb.ca.gov/smp/rice/supply/supply.htm for details.*

Field Equipment

Rice straw baling as a business is new and currently small scale compared to the business of growing rice, and will have to grow to meet the expected demand for straw. Twelve commercial balers were identified in 1997 (Bakker-Dhaliwal, et.al., 1998). Most are engaged in the straw and hay business throughout the year and have access to the appropriate equipment. Rice straw harvesting and handling equipment includes

tractors, rakes, swathers, balers, stackers, trucks and forklifts. It is likely that most growers will hire the work rather than do it themselves. A few will see a business opportunity and develop a straw harvesting enterprise. Some balers currently operating will expand their business to take advantage of this new opportunity, as conditions dictate.

Bakker-Dhaliwal, et.al, (1998), estimated that 140-180 machine systems (swather/tractor-baler/road siding) would be needed to harvest 500,000 dry tons of rice straw with a preliminary investment cost estimate of $14-40 million, exclusive of transportation and storage costs. Anderson Hay and Grain (1998) estimated an equipment complement of 25 big balers, 13 rakes, 37 tractors and 13 stackers would be necessary to harvest 100,000 tons. Sufficient equipment does not appear to be readily available nearby to harvest large amounts of rice straw, so will likely have to be developed locally and/or come from out of the area. Given the rigors of harvesting rice straw, the equipment will probably require modification for rice straw (see following discussion) which will impact its costs and availability.

Field Operation Logistics and Know-how

Although rice straw baling is a new undertaking, many of the principles of good forage harvesting are applicable. But, there will be a learning curve unique to rice fields. For example, balers and growers will have to cooperate to preplan the operation to ensure adequate field access, that levees are open for equipment to pass, that drainage occurs in time to dry the soil, and that adequate staging areas are available to stack bales and load trucks. Each operator will have to learn the best time of day to harvest to achieve suitable moisture content, appropriate size and density of bales for the end-use, to ensure efficient baling and road siding and to meet legal size limits for trucking on public roads. Several unique features distinguish rice straw and rice fields from other forages and require new knowledge and approaches.

- Silica content of 10-12.5% (Fadel, 1994) makes rice straw abrasive to harvesting and handling equipment. Equipment operators must pay more attention to wear points and replace critical components more often.
- Rice straw is available for harvest during a relatively short time during the fall months which requires a concentration of effort, an ‘all hands on deck’ approach.
- Balers must also be mindful of the unique quality considerations associated with the various end uses of rice straw.
- Rice fields are often too wet immediately after grain harvest for baling, so the logistics and operation of balers will be affected. Rice fields are frequently rutted, from harvesting equipment and/or ground rigs and may affect the efficiency of baling operations. Wet fields will affect the bale stack wagon operation and possibly the

baler (Anderson Hay and Grain, 1998). These operators noted rice straw is significantly more difficult to bale than alfalfa, resulting in lower productivity. Modifications are needed to improve traction, power train, engine cooling, and lower ground pressure.

- Pricing custom operations appropriately will be a challenge until there is an adequate track record. Research will help provide some of the new knowledge, but experience will be the primary teacher.

Recommendation: *Research is needed on technology and economics of specialized rice straw harvesting equipment to accommodate the higher wear rate and wet soil conditions in rice fields.*

Storage : Linking Supply and Demand

Rice straw is a storable commodity if it is baled correctly. Because rice straw is harvested in the fall, providing a supply throughout the year requires some form of storage to meet the year-round demand. Increasing demand will in turn stimulate investment in storage. Hence, development of storage structures is central to providing a steady supply of straw, which will encourage growth of demand. Mutual dependency of supply and demand suggests that lack of adequate storage is a key barrier to utilization of rice straw.

Storage systems include uncovered storage, tarps, pole barns, and enclosed metal barns. Currently, there are few permanent storage structures available for rice straw in California and most rice straw is stored uncovered or under tarps.

- *Uncovered Storage*. This is the most common storage method, is essentially without investment costs, and is useful for very short-term storage. Bales are usually stacked at the field side with the intent of quickly moving them to the end user. As wet weather begins, uncovered straw will rot, stacks will start to fall and the value of the straw will rapidly decrease for most uses except perhaps compost. Uncovered storage is practical for those uses that are immediate such as erosion control.
- *Tarps.* Tarps are made of water-repellent fabric which covers the top of the stack and comes part way down the sides. In some cases they can completely enclose the stack. The stacks are placed on a surface that will quickly drain away the water. Tarps are usually tied down to prevent blowing off in the wind. Tarps are common in areas of Oregon where the weather is cold and relatively dry, east of the Cascades. There, they are used as a way to cover straw for short-term use, to extend the summer season. The intent is to provide lower cost, short-term storage. The annual cost of tarp storage is estimated at $4/ton that includes purchase cost of $6/ton, life expectancy of three years, and about $2/ton/year to install and maintain

(Van Mouweirk, 1999). Tarps have lower capital costs than permanent structures, but if the straw is in poor condition, they are expensive. Some long-term tarp storage in California has been used with mixed results. The longer straw remains under tarp storage the greater the potential for loss, from rain wetting the sides and from leaks in the tarp. Some losses have been reported in California rice straw when tarps are used over the winter.

- *Pole Barns*. Few pole barns are available for storing rice straw in California. Pole barns are essentially a roof structure, usually metal, supported by wooden poles. They may have gravel or concrete floors and may be protected on one or more sides from weather. The degree of protection provided from rain determines the quality of straw they store. Pole barns are generally considered better than tarps, particularly if they have partial walls. Since pole barns vary greatly in structure, costs also vary. Cost of a pole barn ranges from \$3-6/ft^2 (Bakker-Dhaliwal, et.al., 1998). In one example, a 1900-ton capacity pole barn had dimensions of 240' x 68', or 16,320 sq. ft. At a cost of \$5/ft^2 to build, the total cost would be \$81,600, or \$42.95/ton capital costs. With pole barns the high capital cost is the primary limitation to building them. Rent of pole barns has been reported in the range of \$4-\$7/year.
- *Enclosed Metal Barns*. Few enclosed metal barns are available for rice straw storage in California. A typical metal barn would have a roof and four completely enclosed sides, with either an aggregate or concrete floor. They offer the best protection for overwinter storage of straw. One estimate (van Mourweik, 1999) of cost to build is \$7-8/ft^2 and a life of 20 years. Using the pole barn example of a structure suitable for 1900 tons, a metal barn would cost \$114,240 to \$130,560 to build.

The location of storage structures is an important consideration. From the view of efficient use of baling equipment, storage should be located in the country close to the fields. From the view of the user, straw should be located at the shipping/processing point. Consolidation of large amounts of straw at a single site is a fire hazard and is probably not desirable. The rice grain industry uses a storage system that includes a combination of country or field side storage sites plus storage at processing sites. During the year, grain is shipped from country sites to the plants. This pattern would be a reasonable one for the straw industry to adopt.

While it is clear that quality storage is desirable, it is less clear how barns will get built. In the short run, the industry will probably rely on cheaper storage alternatives until demand is stable and new businesses get their feet on the ground. Future options for getting storage built might include individual investment or government assistance, or a combination of both, as recommended in the recently released ARB draft report on rice straw supply. Economics of rice straw utilization does not appear to support building barns, leaving some users with no secure supply. Where the cost of storage is supported by the end-use, barn construction could eventually be factored into long-term

straw purchase contracts. However, in the near term, growth of demand would be greatly aided if storage was available. Practitioners in the field have consistently pointed out the need to create storage systems to pave the way to utilization.

Many have suggested a role for government in creating more rice straw storage. A very instructive example is the experience of the state of Oregon, which has had a straw disposal problem from grass seed production in the Willamette Valley. In many respects, the Oregon grass seed problem is very similar to the Sacramento Valley rice straw problem. Discontinuation of burning resulted in several initiatives, one of which was development of a "Pollution Control Tax Credit" program for alternatives to burning and animal waste management. The Oregon Environmental Quality Commission issues a pollution control facility certificate to qualified facilities which enables one to take a state tax credit . "Any Oregon taxpayer that makes a capital investment in a pollution control facility may qualify for a tax credit...the taxpayer seeking a credit must be the business owner, contract purchaser or lessee conducting the business." Approved facilities include "equipment, facilities, and land for gathering, densifying, handling, storing, transporting and incorporating grass straw or straw based products." The taxpayer can take up to 50% of the certified cost of the facility as a tax credit, spread equally over ten years. The actual amount of the tax credit depends on what percent of the facility cost can be attributed to pollution control. Numerous straw storage structures have been built in Oregon with the help of this program. As of Dec, 1998, 338 certificates worth $19,836,788 had been issued in Oregon for alternatives to field burning.

Recommendation: *Government assistance, such as the Rice Straw Tax Credit program, should be investigated to stimulate the construction of storage structures for rice straw. Such a program should have a sunset to get the process started after which market mechanisms would determine the economics of building storage*.

Transportation

The primary rice straw transportation issues are cost, trucking capacity, routing efficiency, and unintended consequences of hauling large amounts of material. Trucking costs are in the range of $10/ton inside a ten-mile radius and $20 for a fifty-mile haul (Hrynchuk, 1998). Hauling can be more expensive than baling and is a significant consideration in utilization projects. Rice straw is low density; research in alternative packing of rice straw might lower the transportation costs. Bakker-Dhaliwal, et.al, 1998, is developing transportation routing information using GIS methods so that distance, cost, speed, etc. can be more efficiently determined.

The *Rice Straw Diversion Plan* suggests there is not adequate trucking capacity to transport 50% of the rice straw within a four to eight week period in the fall. Location of

storage facilities, whether on farm or centralized at the end user, will have a large impact on when and how far straw is hauled, and thus on the number of trucks needed.

Recommendation: *Research on optimizing placement of storage facilities should be encouraged.*

Standards and Grades

End users have differing needs in respect to straw characteristics. Ultimately, straw handlers will need the ability to discriminate various categories of rice straw. This suggests a grading system that derives from straw characteristics that are measurable and which relate to end-uses. A system of standards and grades for rice straw would be helpful in guiding the planning, gathering, and storing operations. It would also help in developing a pricing structure that reflects the costs of meeting end user criteria. No such system exists so straw buyers make their decisions according to subjective criteria based on their personal knowledge of the application.

Recommendation: *The State of California should initiate development of industry specific standards and grades for rice straw, involving industry in the process.*

Processing/Brokerage/Direct Sales

Previous reports of the Rice Straw Burning Alternatives Committee have suggested the need for a rice straw marketplace, a reliable source of quality straw for multiple uses. This is the objective of a first-year recipient of Rice Fund money, Anderson Hay and Grain. Such a facility can serve the marketing needs of the rice straw industry by acting as a broker who acquires straw from producers on behalf of end users, and either ships the straw direct or arranges storage. In addition, it could package or process straw for various applications on contract and maintain a supply of popular straw products (e.g. small bales of various qualities) for direct consumer purchase.

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