1.0 INTRODUCTION

This report provides a description of the structure of the **F**orest and **A**gricultural **S**ector **O**ptimization **M**odel (**FASOM**), a dynamic, nonlinear programming model of the forest and agricultural sectors in the United States. The model depicts the allocation of land, over time, to competing activities in both the forest and agricultural sectors. It has been developed for the U.S. Environmental Protection Agency (EPA) to evaluate the welfare and market impacts of alternative policies for sequestering carbon in trees. The model is also designed to aid in the appraisal of a wider range of forest and agricultural sector policies. In the longer term an expanded version of the model may be used to simulate the effects of climate-induced changes in yields on market behavior and economic agents in both sectors.

The conceptual structure of FASOM is an outgrowth of two previous studies.[1] In the first of these, Adams et al. (1993)[2] modified an existing, price-endogenous, agricultural sector model (ASM) developed by McCarl (McCarl et al., 1993) to include consideration of tree planting and harvest on agricultural land to sequester carbon. While the study was by no means the first to estimate the cost of sequestering carbon, it was a pioneering effort in several respects. First, it provided estimates of the costs of sequestering carbon that took into account the increases in agricultural prices that would occur when agricultural crops were displaced by trees. Second, it presented estimates of the impacts of different size programs on both the total and the distribution of the consumers' and producers' welfare in the agricultural sector. Finally, it showed that harvesting the trees used to sequester carbon had the potential to greatly depress regional stumpage prices in the United States.

An important limitation of this study was that there was no effort to model the dynamics of tree growth. Rather, the trees were assumed to be harvested in a steady state uniform rotation. A subsequent study, by Haynes et al. (1994a), employed the Timber Assessment Market Model (TAMM) and a linked inventory model, called ATLAS, to look at this issue. As expected, the inventory of existing trees acted like a filter, spreading out the period of time over which the trees that had been planted to

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[1] In its broad form the forest sector of FASOM is a "model 2" harvest scheduling structure as described by Johnson and Scheurman (1977) or a "transition" timber supply model as outlined by Binkley (1987). It is related to previous models of this sort as developed by Berck (1979) and to the **T**imber **S**upply **M**odel (TSM) developed by Sedjo and Lyon (1990). In both FASOM and TSM the forest inventory is modeled in an even-age format using a set of discrete age classes with endogenous decisions on management intensity made at time of planting. Only a single demand region is identified and market interactions are restricted to the log level. The TSM is solved using methods of optimal control with an annual time increment. FASOM, using a decade time step, is solved using nonlinear programming.

[2] This paper was originally presented as a paper in 1991 at the annual meeting of the Western Economics Association.

sequester carbon were harvested. Modeling the dynamics of the forest inventory had the effect of damping the decreases in stumpage prices relative to the results in Adams et al. (1993).

The structure of the models used in these two previous studies did not make it possible to look at the effects of future price expectations on the behavior of the owners of existing private timberland; their subsequent reaction to lower expected stumpage prices; and the likely impacts on the total amount of carbon sequestered. They assumed, in effect, that the harvest and reforestation (or afforestation) decisions of private timberland owners were not significantly influenced by the planting of millions of acres of potentially-harvestable timber by farmers. However, if timberland owners knew these trees would be harvested sometime in the future, they would probably take actions to reduce the size of their inventory holdings, either by harvesting sooner, reforesting at a lower management intensity, or by shifting investment to other sectors of the economy. This would reduce the price impacts of "tree dumping" from the agricultural sector on the forest sector, but it would also reduce the amount of carbon that was sequestered in total.

This limitation could only be addressed by specifically linking the forest and agricultural sectors in a dynamic framework, so that producers in both sectors could, in effect, foresee the future consequences of alternative tree planting policies and take actions to accommodate the future effects. Thus the need to model the intertemporal optimizing behavior of the economic agents that would be affected by carbon sequestration policies was a major driving force in the creation of FASOM.

Linking the two sectors in a dynamic framework also has a number of other advantages related to the effects of tree planting, forest and farm management programs on land transfers. Existing studies of land use transfers between the agricultural and forest sectors are, at best, studied using a static, partial equilibrium (i.e., one-sector) framework in which land prices between the two sectors are not allowed to resolve. FASOM, on the other hand, allows transfers of land between sectors based on its marginal profitability in all alternative forest and agricultural uses over the time horizon of the model.

1.1 FASOM FEATURES

The modeling system includes a set of core capabilities. A brief description of these features follows.

1. **Based on joint, price-endogenous, market structure.** The agricultural and forest product sectors are linked in a single model and compete for a portion of the land base. Prices for agricultural and forest sector commodities are endogenously determined given demand functions and supply processes. Competition for land between agricultural and timberland enterprises provides the basis for simultaneous price determination in both sectors. The structure of the two sectors is based in part on

elements of the TAMM (Adams and Haynes, 1980) and ASM (McCarl et al., 1993) models.

Land uses can change over time, based on expectations about the future. For example, if there is upward pressure on agricultural prices and downward pressure on stumpage prices as a result of a specific tree planting policy, there is the potential to convert forest land into crop and pasture land. The land use shifts that occur in FASOM are based on comparisons of endogenously determined returns to land in alternative uses.

2. **Model based on welfare accounting.** The model provides estimates of total welfare, and the distribution of welfare, broken down by agricultural producers, timberland owners, consumers of agricultural products and purchasers of stumpage.

3. **Uses an optimization approach.** FASOM is a nonlinear mathematical program (i.e., optimizing model). The model maximizes the net present value of the sum of: a) consumers' and producers' surplus (for each sector) with producers' surplus interpreted as the net returns from forest and agricultural sector activities. GAMS (General Algebraic Modeling System) is used to define and solve the model (see Appendix D for overview of file structure). Supply curves for agricultural products, sequestered carbon and stumpage are implicitly generated within the system as the outcome of competitive forces and market adjustments. This is in contrast to supply curves that are estimated from observed, historical data. This approach is used in part because FASOM will be used to analyze conditions which fall well outside the range of historical observation (such as large scale tree-planting programs).

4. **Incorporates expectations of future prices.** Farmers and timberland owners are able to foresee the consequences of their behavior (when they plant trees or crops) on future stumpage and agricultural product prices and incorporate that information into their behavior. The FASOM model uses deterministic expectations, or "perfect foresight", whereby expected future prices and the prices that are realized in the future are identical.

5. **Uses methods similar to the ATLAS inventory projection model and data drawn from the RPA Timber Assessment.** FASOM models forest inventory using the same age-based structure as ATLAS and basic inventory data drawn from the Forest Service's 1993 RPA Timber Assessment Update data base (Haynes et al., 1994b). Relative density adjustment mechanisms and other growth and yield projection guides are based on those in the ATLAS system.

6. **Includes forest management alternatives.** Unlike TAMM, timber management investment decisions in FASOM are endogenous. Actions on the inventory are depicted in a framework that allows timberland owners and agricultural producers to institute management activities that alter the inventory consistent with maximizing the net present value of the returns from the activities in which they engage.

7. **Projects *changes* in carbon inventory in both sectors.** The modeling system performs carbon accounting in both sectors. Carbon accounting in the model includes carbon in growing stock, soil, understory, forest floor, woody debris, and in forest products, landfills, and displaced fossil fuels.

8. **Can be expanded easily to include new features.** The programming structure of FASOM allows projections of the forest sector either alone or linked to the agricultural sector and the addition of a wide array of activities and/or constraints to emulate other market or policy features in either sector.

9. **Can evaluate a wide range of policies, scenarios, and sensitivities.** The modeling system is designed to provide information about the effects of a wide range of potential policies on carbon sequestration, market prices, land allocation and consumer and producer welfare under alternative supply and demand scenarios and eligibility/participation constraints. The modeling system is designed so that it is possible to evaluate the sensitivities of these policies and their results to different assumptions about policy structure, as well as financial assumptions.

10. **Can be used to evaluate forest only, agricultural only, or linked sector issues.** The modeling system is designed to work on the forest and/or agricultural sectors either independently or simultaneously. This allows one to study sectoral issues either independently or across the two sectors.

1.2 SCOPE AND ORGANIZATION OF THIS REPORT

This report describes how the capabilities, described above, are built into the structure of the FASOM model. The discussion is primarily in conceptual terms as opposed to a detailed mathematical depiction of the model.

The report is divided into 4 sections and four appendices. Following the Introduction, Section 2.0 provides an overview of the major features of the model, such as the regional delineation and the basic structure of the forest, agricultural and carbon accounting sectors in the model. Section 3.0 presents a simplified tableau of FASOM and uses this to describe, in a general way, the variables and equations that are in the model and the functions they serve. Section 4.0 describes the outputs of the FASOM model, discusses how the model can be used to evaluate alternative policies for sequestering carbon, and outlines potential future directions for the model. Appendix A contains additional detail on the scope of the agricultural model while Appendix B contains additional detail on the scope of the forest model. Appendix C contains the current version of the main FASOM model code. Appendix D provides a description of the computer program and data file structure for the FASOM modeling system as a whole. Finally, Appendix E contains a detailed listing of the outputs of the model.

2.0 MODEL OVERVIEW

This section provides a brief description of the major features and important assumptions of the FASOM model. It is followed by brief discussions of each of the sectors in the model: forest, agriculture, and carbon accounting.

2.1 MODEL FEATURES

Operationally FASOM is a dynamic, nonlinear, price endogenous, mathematical programming model. The generic meaning of these terms is as follows. FASOM is dynamic in that it solves jointly for the multi-market, multi-period, equilibrium in each agricultural and stumpage product market included in the model, over time, and for the intertemporal optimum in the asset market for land. FASOM is nonlinear in that it contains a nonlinear objective function, representing the sum of producers' and consumers' surpluses in the final markets included in the model. FASOM is price-endogenous in that the prices of the products produced in the two sectors are determined in the model solution. Finally, FASOM is a mathematical programming model because it uses numerical optimization techniques to find the multi-market price and quantity vectors that maximize the value of the objective function, subject to a set of constraints and associated right-hand-side (RHS) values that characterize: the transformation of resources into products over time, initial and terminal conditions, the availability of fixed resources, and policy constraints.

FASOM employs 11 supply regions and a single national demand region. The supply regions, as shown in Figure 2-1, are: Pacific Northwest-West, Pacific Northwest-East, Pacific Southwest, Rocky Mountains, Northern Plains, Southern Plains, Lake States, Corn Belt, South Central, Northeast, and Southeast. Alaska and Hawaii are not included in the FASOM model. Land use and exchanges of land between sectors in some of the regions are constrained for empirical or practical reasons. Under the current climatic regime, environmental conditions in the Northern Plains states are not conducive to significant amounts of cost-effective commercial forest or carbon sequestration activities. However, these States are important agriculturally and are included in the model only with agricultural sectors. The same is true for the western portions of Texas and Oklahoma (i.e., the Southern Plains). Finally, the Pacific Northwest (PNW) was divided into an eastern region (PNWE) and a western region (PNWW) to reflect differences in environmental conditions and production practices on either side of the Cascade Mountains in Oregon and Washington. In the PNWW region it is assumed that land is in equilibrium between forest and agricultural use for the various available classes and sites. A substantial amount of land transfer between agricultural and forestry uses is not believed to be appropriate or likely. For this reason, and because PNWW agricultural production of the crops modeled in ASM is relatively small, only the forest sector is included in this region.

Figure 2-1. **FASOM Regions.**

Production, consumption and price formation are modeled for hardwood and softwood sawlogs, pulpwood, and fuelwood in the forest sector as well 75 primary and secondary cropand livestock commodities in the agricultural sector. The model is designed to simulate market behavior over a 100-year period, with explicit accounting on a decade by decade basis. The model incorporates national demand curves for forest and agricultural products by decade for the projection period 1990-2080. The production component includes agricultural crop and livestock operations as well as private nonindustrial and industrial forestry operations. Harvests from public forest lands are treated as exogenous. From an agriculture policy perspective, the model includes 1990 farm programs for its initial decade then operates without a farm program from thereon.

The forest sector of FASOM depicts the use of existing private timberland[3] as well as the reforestation decision on harvested land. The flow of land between agriculture and forestry is also an endogenous element of the model. Forested land is differentiated by region, the age cohort of trees,[4] ownership class, cover type, site condition, management regime, and suitability of land for agricultural used. FASOM accounts for carbon accumulation in forest ecosystems on private timberland, as well as the fate of this carbon, both at and after harvest.

The possibility of planting trees with a rotation length which would carry them beyond the explicit time frame of the model necessitates the specification of terminal conditions. At the time of planting producers should anticipate a flow of costs and returns which justify stand establishment costs. The planting of a stand with an expected 30 year life in year 80 of a 100 year projection is potentially problematic, however, because the anticipated harvest date is beyond the model time frame. A mechanism is needed to reflect the value of inventory carried beyond the explicit model time frame. This is done with "terminal conditions" which represent the projected net present value of an asset for all time periods beyond the end of the model projection. Terminal conditions in FASOM are resolved using downward sloping demand curves for the terminal inventory.

Four types of terminal inventory are valued in FASOM: a) initial stands which are not harvested during the projection; b) reforested stands remaining at the end of the projection; c) undepreciated forest processing capacity; and d) agricultural land retained in agriculture. Specific valuation approaches for each of these elements are discussed in Section 2.5.

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[3] Timberland is the subset of forestland that is capable of producing at least 20 cubic feet per acre per year of industrial wood at culmination of mean annual increment and is not withdrawn from timber harvesting or related timbering activities.

[4] Forest lands are grouped in ten 10-year cohorts: 0 to 9 years, 10 to 19, ... , 90 + years. Harvesting is assumed to occur at the midyear of the cohort.

2.2 FOREST SECTOR

The forest sector in FASOM consists of the following basic building blocks:

- Demand functions for forest products
- Timberland area and inventory structure and dynamics
- Production technology and costs.

2.2.1 Product Demand Functions

FASOM employs a single national demand region for forest products which treats only the **log** market portion of the sector. There is, in fact, very little interregional shipment of logs in the U.S. forest sector. Competitive price relations between regions at the log and stumpage market levels are maintained through extensive trade and competition at the secondary product level (lumber, plywood, pulp, etc.). Use of a single consuming region for logs emulates the effects of competition at higher market levels without the use of an explicit representation of activity at these levels.

The demand for logs derives from the manufacture of products at higher market levels. In FASOM log demands are aggregated into six categories: sawlogs, pulpwood, and fuelwood for both softwoods and hardwoods. Log volumes are adjusted to exclude all but the growing stock portion.[5] Thus, demand is for growing stock log volumes delivered to processing facilities. Log demand curves are derived from solutions of the TAMM and NAPAP (Ince, 199?) models by summing regional derived demands for logs from manufacturing at higher market levels (sawlogs from TAMM, pulpwood from NAPAP). Fuelwood demand, which is not price sensitive in TAMM, is represented by a fixed minimum demand quantity and a fixed price. National fuelwood demand volumes by decade were derived from appropriate scenarios in the 1993 Timber Assessment Update report (Haynes et al., 1994b). Demand curves are linearized about the point of total decade quantity and average decade price. Demand curves shift from decade to decade, reflecting changes in the underlying secondary product demand environment, secondary processing technology and secondary product capacity adjustment across regions.[6]

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[5] Nongrowing stock volumes are included only for carbon accounting.

[6] For both sawlogs and pulpwood, "national" price is taken as the highest of the regional average prices observed during the 1980s. Regional prices are then derived from the national price by deducting the historical average difference between the national and regional price. These differences become the "transportation" costs in

Off-shore trade in forest products occurs at the supply region level and includes both softwood and hardwood sawlogs and pulpwood. Fuelwood is not traded. Price-sensitive, linear demand (export) or excess supply (import) relations were developed for the various regions and products as appropriate for their current trade position. For example, the Pacific Northwest-West region faces a net export demand function for softwood sawlogs but no offshore trade demand for hardwood products or other softwood **log** products.

2.2.2 Inventory Structure

Forest inventory in FASOM is divided into a number of strata, each representing a particular set of region, forest type (species), private ownership, site class, age, agricultural use suitability, and timber management intensity characteristics. Each stratum is characterized in terms of the number of timberland acres and the growing stock volume per unit area (in cubic feet per acre) it contains. Inventory estimates for the existing forest inventory on private timberland are drawn from data used in the 1993 RPA Timber Assessment Update (Haynes et al., 1994b).

The descriptors used in FASOM to characterize the structure of the inventory on private timberland in each region are as follows:

< **Owner groups.** Forest industry and other private[7] (the traditional definitions are used, in which industrial owners are integrated to some form of secondary processing and other private owners are not).

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the market model and are assumed to be constant over the projection. Since all transactions are measured "at the mill" or in "mill delivered" terms, intraregional log haul costs are included in prices. Demand equations for sawlogs for the five initial decades of the projection were derived from TAMM by summing regional derived demand relations for sawlogs (with prices adjusted to the national level). Demand elasticities varied between -0.34 and -0.44 for softwood and -0.19 and -0.22 for hardwood. Pulpwood demand relations were derived from the basic NAPAP roundwood consumption and price projections assuming a linear demand approximation and a demand elasticity of -0.4. In this manner, the projected log demand equations reflect the specific log processing technology assumptions incorporated in the Update analysis as well as the underlying product demand and macroeconomic forecasts. Demand projections for different assumptions on technology trends or demand determinants (as in the sensitivity analyses) were derived from appropriate projections of TAMM and NAPAP. In addition, for any given policy (public cut) scenario the evolution of product demand is likely to vary in response to trends in prices of forest products and substitutes in a manner unique to that scenario. We approximate this dynamic development of log demand by rerunning the TAMM and NAPAP models with the appropriate scenario input to obtain revised demand equation projections.

[7] Unlike Powell et al. (1993), the Other Private inventory in FASOM does not include Native American Lands. Harvests on these lands are included with the Other Public exogenous harvest group.

- **Forest type/species.** Softwood and hardwood in the current rotation and immediately preceding rotation.
- **Suitability for agricultural use.** Land is classified by type of alternative use for which it is suited (crop, pasture, or forest) and by its present use (crop, pasture, or forest). Multiple suitability classes are only used for the other private ownership, as all forest industry timberland is classified as forest only.
- **Site quality classes.** High, medium, and low based on the Forest Service productivity classification scheme.
- **Management intensity classes.** Three current classes for both private owner groups (high, medium, and low) are based on a qualitative characterization, drawn from the management intensity classes used in the ATLAS system (Haynes et al., 1994a). A fourth class, low-low, is used to characterize any future harvested timberland that is totally passively managed thereafter and is not converted to agriculture.
- **Age cohorts.** Ten-year intervals, based on FIA descriptions, from the 0-9 year class (just regenerated) to the 90+ year class.

Any portion, from 0 to 100 percent, of a stratum can be harvested at a time. The harvested acres then flow back into a pool, from which they can be allocated for several different modes of regeneration as new timber stands or shifted to agricultural use. FASOM allows for newly regenerated stands, whether on timberland or agricultural land, to be subject to several different levels of management intensity. While management intensity shifts cannot occur after a stand has been regenerated (as can occur within ATLAS), this is not thought to be a problem, given that the model employs perfect foresight in allocating land to competing activities.

FASOM simulates the growth of existing and regenerated stands by means of timber yield tables which give the net wood volume per acre in unharvested stands for strata by age cohort. Relative density adjustment mechanisms (Mills and Kincaid, 1992) were used to adjust tree volume stocking levels in deriving yields for existing timberland and for any timberland regenerated into the low timber management class. Timber yields for plantations on agricultural lands are based on the most recent, reconciled estimates by Moulton and Richards (1990) and Birdsey (1992a).[8]

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[8] Timber yields contained in Moulton and Richards (1990) were derived from estimates for plantations from Risbrudt and Ellefson (1983). In some cases such as for the Rocky Mountains region, these estimates have been the subject of some debate because they are fairly high relative to yields on commercial timberland. Estimates of timber yields used by Birdsey (1992a), based on yield tables in ATLAS, used for the RPA, are much lower. The two groups

The above growth and inventory structure is used only for private timberland.[9] Two additional categories of forest land need to also be addressed: public timberlands and nontimberland forest land. Private timberland constitutes about 70 per cent of the timberland and about 50 per cent of the total forest land in the United States. Timberland in various public ownerships--including Federal, State and local owners--represents about 30 percent of the timberland and about 20 percent of the forest land in the United States. Data from which to sufficiently characterize the site quality and age structure of the public inventory in the East were not available when parallel private timber data sets were assembled for the FASOM study. In the West, which contains the majority of public timberland, the USDA Forest Service is in the process of collecting the necessary data for public timberlands to augment the private inventory data. Currently, the data that do exist for public timberlands in the West are relatively sparse and difficult to organize, and the earliest date that a full reliable set may possibly be available is 1997 for use in the next RPA Assessment. Because of the current unavailability of data for key regions and the complexity and cost associated with developing an inventory of public timberlands, FASOM does not model their inventory. Harvest on these lands is taken as exogenous. This is consistent with current public policy and the expected direction of future policies that will likely place increasing weight on the management of public lands for nonmarket benefits.

Nontimberland, forested land constitutes about 30% of the forestland in the United States. This includes transition zones, such as areas between forested and nonforested lands that are stocked with at least 10% of forest trees. It also includes forest areas adjacent to urban and built-up lands (e.g., Montgomery County, VA) and some pinyon-juniper and chaparral areas of the West. While this area is large, the data to characterize the site class and inventory structure of this inventory are much poorer than for public lands. Also, the fact that this land is not very productive and is widely dispersed among private owners with a variety of management objectives makes it a very difficult "target" for either regulatory or incentive-based forest management/carbon sequestration programs. In light of these difficulties, harvest on this land is taken as exogenous and changes in inventory volumes or structure are not accounted for in the model.

2.2.3 Production Technology, Costs, and Capacity Adjustment

Harvest of an acre of timberland involves the simultaneous production of some mix of softwood and hardwood timber volume. In FASOM this is translated into hardwood and softwood products

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of researchers are currently working on reconciling their differences.

[9] Under Forest Service definitions (adopted here), forest land is any land with at least 10 percent tree cover (as would be identifiable in an aerial photograph). Timberland is forest land that has the **capability** to grow at least 20 cubic feet per acre per year of commercial timber products.

(sawlogs, pulpwood, and fuelwood) in proportions that are assumed to be fixed. The product mix changes over time, as the stand ages, and between rotations if the management regime (intensity) changes. Downward substitution (use of a log "normally" destined for a higher valued product in a "normally" lower valued application) is allowed when the price spread between pairs of products is eliminated. Sawlogs can be substituted for pulpwood and pulpwood, in turn, can be substituted for fuelwood, provided that the prices of sawlogs and pulpwood, respectively, fall low enough to become competitive substitutes for pulpwood and fuelwood, respectively. This "down grading" or interproduct substitution is technically realistic and prevents the price of the pulpwood from rising above that of sawlogs and the price of fuelwood from rising above that of pulpwood.

Strata in the inventory have specific management (planting and tending) costs that vary by inventory characteristics and the type of management. These costs were derived from a variety of sources, including Moulton and Richards (1990) and those used in the 1989 RPA Timber Assessment (Alig et al., 1992).[10] Each product, in turn, has specific harvesting and hauling costs (hauling in this instance relates to the movement of logs from the woods to a regional concentration or delivery point). These costs were derived from the TAMM data base and cost projections used in the Forest Service's 1993 RPA Timber Assessment Update (Haynes et al., 1994b).

Consumption of sawlogs and pulpwood in any given time period is restricted by available processing capacity in the industries that use these inputs. Investment in additional capacity is made endogenous by allowing purchase of capacity increments at externally specified prices. This raises the current capacity bound and the bounds in future periods as well. It also reduces producers' surplus by the cost of the capacity acquisition. Over time, capacity declines by an externally specified depreciation rate. Capacity increments in any period are also limited by preset bounds. Since capacity may be added but not fully depreciated before the end of the projection, the objective function is augmented by a term giving the current market value of the undepreciated stock.

2.3 AGRICULTURAL SECTOR

In developing FASOM, two approaches to modeling the agricultural sector were considered. The first involved representing the agricultural sector through carbon sequestration supply curves. These curves would capture the relationship between a) welfare; b) the amount of carbon that could be sequestered; and c) the acreage required to sequester that carbon. This approach would reduce the size of FASOM, so that the model would not have taken as long to run. However, the supply curves would depend on policy variables that one would like to vary from run to run. This would necessitate the

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[10] See Appendix B for a more detailed description of the timber growth and yield, management costs and assumptions about trends in nonagricultural uses of forested lands.

development of a large number of supply curves prior to running the model for policy analysis purposes. Each supply curve would be developed by running the ASM model a number of times.

The second approach involves "importing" a version of ASM model into FASOM. By doing this, the need to conduct a large number of ASM runs to develop supply curves is avoided. The main disadvantage of this approach is that it increases the size of FASOM. However, the modeling team decided that the advantages of this approach outweighed its costs, especially given the processing speed of modern work stations.

The ASM model that has been adapted for use in FASOM is described in detail in Appendix A with an overview given in McCarl et al. (1993). The only real difference from the full ASM is in regional delineation. The model here is aggregated to the 11 FASOM regions (without any variables in the PNWW region) whereas the ASM model is organized around 63 state-level and, in some cases, sub-state level production regions.

Operationally, ASM is a price-endogenous agricultural sector model. It simulates the production of 36 primary crop and livestock commodities and 39 secondary, or processed, commodities. Crops compete for land, labor, and irrigation water at the regional level. The cost of these and other inputs are included in the budgets for regional production variables. There are more than 200 production possibilities (budgets) representing agricultural production in each decade. These include field crop, livestock, and tree production. The field crop variables are also divided into irrigated and nonirrigated production according to the irrigation facilities available in each region.

The secondary commodities are produced by processing variables. They are soybean crushing, corn wet-milling, potato processing, sweetener manufacturing, and use feed mixing of various livestock and poultry feeds, and the conversion of livestock and milk into consumable meat and dairy products. Processing cost of each commodity is calculated as the difference between its price and the costs of the primary commodity inputs.

A unique feature of ASM is the method it uses to prevent unrealistic combinations of crops from entering the optimal solution, a common problem in mathematical programming models. While the agricultural sector in FASOM is divided up into 10 "homogenous" production areas, each of which has available a large number production possibilities, it is often the case that the optimal, unconstrained solution in some regions is represented by one crop budget -- complete specialization. In reality, risks associated with weather and the effects of other "exogenous" and sometimes transient variables on agricultural prices lead to diversification in crop mixes and such a representation cannot capture the full factor-product substitution possibilities in each of those areas. In these cases, it can lead to quite misleading results. This is avoided by requiring the crops in a region to fall within the mix of crops observed in the Agricultural Statistics historical cropping records. The model is constrained so that for each area the crop mix falls within one of those observed in the past 20 years.

Primary and secondary commodities are sold to national demands. These demand functions are characterized by either constant elasticity of substitution or linear functions. The integrals of these demand functions represent total willingness to pay for agricultural products. The difference between total willingness to pay and production and processing costs is equal to the sum of producer and consumer surplus. Maximization of the sum of these surpluses constitutes the objective function in ASM. This objective function is included in FASOM to characterize the behavior of economic agents in the agricultural sector. This formulation is used for the forest sector, as well.

The ASM agricultural sector is static, in contrast to the dynamic nature of the forest sector characterization. Modeling agricultural activity in a static framework does not introduce complications for two reasons. First, the crops depicted in the model are planted and harvested in a single year. Second, agricultural land that is planted to trees becomes a part of the forest inventory (although the classification of agricultural land is not lost) and is treated, in a general way, like other acres in the forest inventory. Consequently, the planning problem simulated in FASOM allows land owners to foresee the profitability consequences of all the possible agricultural and forest uses of their land, over time. Typically, yields on agricultural land are higher than on private timberland, but these productivity differences are reflected in the growth and yield tables applied to trees on that land. Once a stand is harvested, it can be regenerated as forested land, or it can be returned to agricultural use. The method used in FASOM to allow land use shifts will become clearer after the reader has seen the FASOM tableau in Section 3.0.

The most important feature about the land use decision that is simulated in FASOM is that, in each period, owners of agricultural land can decide:

< Whether to keep each acre of land in agricultural production or plant trees

< What crop/commodity mix to plant and harvest, if the land stays in agricultural land use

< What type of timber management to select, if the land is to be planted in trees.

These decisions are made entirely on the basis of relatively profitability of land in its various competing alternative uses over the life-span of the foreseeable choices (for land in either crops or trees).

Correspondingly, owners of timberland can decide in each period:

< Whether to harvest a stand or keep it for another decade

- Whether to replant a harvested stand in trees or convert to agricultural crops
- What type of timber management to select if the land is planted in trees
- What crop/commodity mix to plant and harvest, if the land is converted to agricultural land use.

2.4 CARBON SECTOR

The carbon sector in FASOM was designed with a number of different features in mind. First, FASOM is able to account for changes in the quantities of carbon in the major carbon pools in private timberland and cropland. Second, the carbon sector in FASOM is structured such that policy constraints can be imposed on either (or both) the size of the total carbon pool at any given time or the rate of accumulation of carbon from year to year. Third, these constraints can be imposed by region, owner group, land class, etc., consistent with proposed policy instruments. Finally, the carbon sector has been designed so that carbon can be valued in the objective function, instead of constrained to meet specific targets. This makes it possible to model carbon subsidies directly in the model without having to estimate carbon equivalents associated with specific subsidy prices.

The carbon accounting part of FASOM performs the following basic functions:

- It accounts for the accumulation of carbon in forest ecosystems on existing forest stands in the existing private timberland inventory during the simulation period.
- It accounts for the accumulation of carbon in forest ecosystems on both regenerated and afforested stands during the simulation period.
- It accounts for carbon losses in nonmerchantable carbon pools from stands that are harvested from the time of harvest until the stand is regenerated or converted into agricultural land.
- It accounts for carbon "decay" over time, after harvested stumpage is transformed into products.
- It accounts for carbon on agricultural lands.

The carbon accounting conventions associated with carbon in growing stock biomass and in the soil, forest floor and understory closely follows the methodology of Birdsey (1992b). Recently, Turner et al.

(1993) have developed a somewhat different approach to carbon accounting, taking into account the buildup and decay of woody debris on forest stands. The carbon accounting in FASOM includes all of these carbon pools. In adapting these two approaches to FASOM, every effort has been made to preserve flexibility in two ways: a) so that new empirical findings can be integrated into the existing structure; and b) so that changes can be made to this structure, if warranted, and the data are available to support it.

The carbon accounting structure in FASOM is depicted graphically in Figure 2-2. In FASOM, carbon in the forest ecosystem in stands in the existing inventory is divided into two broad pools. The first of these pools is tree carbon (A), which includes carbon in the merchantable portion of the growing stock volume and in the unmerchantable portion of growing stock volume, consisting of bark, roots and branches. The second pool consists of what is labeled ecosystem carbon (C), which includes soil

Figure 2-2. Carbon Sector Structure.

carbon, understory carbon and forest floor carbon.

When a cohort of trees is harvested in FASOM, the merchantable and unmerchantable portions of tree carbon are physically separated and follow different life cycles. In any period, merchantable carbon follows one of three different paths. In any given period, some portion of this carbon pool is stored in wood products or landfills (A_1), or it is burned (A_2), or it oxidizes to the atmosphere in the form of decay. However, not all of the carbon that is burnt is lost immediately in FASOM. In any given period, some portion of it displaces existing fossil fuel emissions, while the remainder represents emissions to the atmosphere. In FASOM, the fractions that determine the distribution of merchantable carbon and burned carbon change from period to period.

Nonmerchantable carbon has a somewhat simpler life-cycle in FASOM. The fraction of the growing stock that is not harvested represents woody debris or, as depicted in Figure 2-2, residue. In any given period, some portion of this residue survives, while the remainder is oxidized in the form of decay. As in the case of the merchantable carbon pool, the fractions that determine the distribution of nonmerchantable carbon change from year to year.

The continuity of ecosystem carbon over time is somewhat more complicated to characterize, and we leave that for the discussion of soil carbon in Section 2.4.1.

2.4.1 Preharvest Carbon Accumulation

In FASOM, carbon is accumulated on existing forested land, on agricultural lands that are converted into forested land, and on any land that is planted in trees in subsequent rotations past the first. As stated earlier, the total carbon stored in the forest ecosystem of an unharvested stand is composed of the following four carbon "pools":

- Tree carbon
- Soil carbon
- Forest floor carbon
- Understory carbon.

Tree Carbon

On average, tree carbon ranges from as low as about 30 per cent of ecosystem carbon to about half of total ecosystem carbon, depending upon species, region and age. Tree carbon on a stand in FASOM, prior to harvest, is the product of three factors: 1) merchantable volume; 2) the ratio of total volume to merchantable volume in the stand; and 3) a carbon factor that translates tree volume into carbon. Merchantable volume, by age, on each representative stand is obtained from the growth and yield tables in the model. The volume factor and carbon factor parameters vary by species and region and are obtained from Birdsey (1992b).

Soil Carbon

Of the four pools, soil carbon is, on average, the second-largest contributor to total ecosystem carbon.[11] Our treatment of this pool generally follows that of Birdsey (1992b). This approach, which is also applied to forest floor and understory carbon, is represented graphically in Figure 2-3. For both afforested and reforested stands, the approach assumes that soil carbon is fixed at a positive, initial level (that varies by land type and region) upon regeneration of a new stand. In afforested stands, soil carbon then increases by a fixed annual increment until it reaches another fixed value (that varies by region and species) at a critical age (somewhere between age 50-60). In reforested stands, soil carbon decreases initially and then increases until it once again reaches the initial level at the critical stand age. After that, soil carbon increases at a decreasing rate over time, until the tree is harvested. (The post-

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[11] For some species, in some regions, soil carbon yield is actually larger than tree carbon yield at reasonable rotation ages.

harvest pattern of soil carbon, and for understory and forest floor carbon, as shown in Figure 2-3, will be discussed in Section 2.4.2.)

Figure 2-3. Ecosystem Carbon Structure.

Note that, in Birdsey's formulation, soil carbon is independent of tree carbon and merchantable volume. Consequently, soil carbon can be calculated outside the nonlinear programming (NLP) part of FASOM. In FASOM, soil carbon varies by region, land type, species and age of a cohort. Estimates of soil carbon, by region, forest type, land type and age were obtained from USDA.[12] These tables were aggregated into hardwoods and softwoods using forest-type - species distribution information for 1987 from Waddell et al. (1989).

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[12] Personal communications with Rich Birdsey, North East Forest Experiment Station, Radnor PA, during the period September 1992 through June 1993.

Forest Floor Carbon

Forest floor carbon constitutes the third largest carbon storage pool, but is much smaller than the other two. Birdsey treats forest floor carbon in a fashion similar to soil carbon. That is, forest floor carbon values are fixed at regeneration, and then increase by a constant annual increment up to another fixed value at a given critical age. Once the critical age is achieved, forest floor carbon increases at a declining rate over time, until the tree is harvested. As with soil carbon, forest floor carbon is independent of tree carbon and merchantable volume. Consequently, it can be calculated outside the NLP part of FASOM. Like soil carbon, forest floor carbon varies by region, land type, species and age of a cohort. Estimates of forest floor carbon, by region, forest type, land type and age were obtained from USDA. These tables were aggregated into hardwoods and softwoods using forest type - species distribution information for 1987 from Waddell et al. (1989).

Understory Carbon Yield

Understory carbon yield is quite small, usually less than a percent of total ecosystem carbon. In Birdsey's formulation, understory yield is fixed at age 5, depending upon region and species. Understory yield increases from age 5 to a critical age (50 or 55) by a constant annual increment. Understory yield at the critical age, and in all subsequent years, is computed as a fixed fraction of tree carbon yield, that varies between about 0.007 and 0.02, depending upon region and species. Note that, unlike soil carbon and forest floor yields, understory yield does depend on tree carbon yield.

Since understory carbon is such a small fraction of the total carbon in a forest ecosystem and because it is only dependent on tree carbon yield for a portion of the life-cycle of a tree, we decided to model understory as carbon yield as effectively independent of tree carbon yield in the model. As such, this pool could be treated just like soil and forest floor carbon. Like the above two carbon pools, understory carbon varies by region, land type, species and age of a cohort in FASOM. Estimates of understory carbon, by region, forest type, land type and age were obtained from USDA. These tables were aggregated into hardwoods and softwoods using forest type - species distribution information for 1987 from Waddell et al. (1989).

2.4.2 Carbon at Harvest

FASOM simulates the fate of carbon, stored in the forest ecosystem, when a stand is harvested. The fate of carbon at harvest is followed in each of the four pools - tree carbon, soil carbon, forest floor and understory carbon.

Tree Carbon

As stated previously, tree carbon is divided into two smaller pools: 1) merchantable carbon that is translated into products; and 2) nonmerchantable carbon, consisting of carbon in bark, branches and leaves, etc., that is not harvested and not useable or is not harvested and below ground carbon in roots. Each of these pools is a fixed fraction of tree carbon at the harvest age, as determined by the region- and species- specific volume factors.

When a cohort is harvested in FASOM, the fraction of total tree carbon that is merchantable is maintained. No losses occur at harvest to this fraction. The remaining fraction - carbon that is in nonmerchantable timber - is adjusted to reflect immediate harvest losses. The fraction of tree carbon left on site immediately after a timber harvest was determined by adjusting the nonmerchantable fraction derived from Birdsey's volume factors to agree with information about the magnitude of this fraction from Harmon (1993).

Soil, Forest Floor, and Understory Carbon

The treatment of soil, forest floor and understory carbon at harvest is illustrated in Figure 2-3. When a stand is harvested it is assumed that carbon in each of these pools will return to an appropriate initial value by the end of the decade period in which harvesting occurred. The appropriate initial level depends upon the use to which the stand will revert in the subsequent rotation. If a stand that is in a forest use remains in a forest use, the appropriate initial level for carbon in these pools is that of a forested stand. If a stand that is in a forest use rotates back into agriculture, then the appropriate initial level for carbon in these pools is that for agricultural land.

2.4.3 Carbon Fate in Wood Products and Woody Debris

FASOM physically tracks the fate of carbon, after harvest, from both merchantable and nonmerchantable timber carbon pools.

Merchantable Carbon

FASOM translates harvested stumpage into three products: sawlogs, which are used for lumber, plywood, and other applications requiring large diameter logs; pulpwood, which is used for paper products; and fuelwood, which is burned. The life-cycle of each of these harvested products can vary greatly depending on both short term fluctuations in relative prices and long-term technological change. However, the life-cycle of these products in these later life-cycle phases is not modeled as an economic decision in FASOM. Instead, data developed using the HARVCARB model (Row, 1992), is used to simulates the fate of carbon in trees after they are harvested, converted into wood and paper products, are used in a variety of ways and then burned or disposed in landfills.

Specifically, HARVCARB outputs are used to model the fate of products in the sawlog and pulpwood products, over time. The fate of carbon for each product is determined by a set of coefficients, showing the "average" fraction of merchantable carbon remaining after harvesting a specific cohort in each subsequent time period in four different "uses": 1) wood products in use; 2) wood products in landfills;[13] 3) burned wood products; and 4) emissions to the atmosphere (i.e., oxidization). These carbon fate coefficients vary by product, species, and length of time after harvest. The fate of carbon in wood that is burned is determined by fixed proportions that divide this carbon into two categories: displaced fossil fuels, an addition to the carbon pool, and emissions to the air. These fractions only apply for a single decade. All wood is assumed to be burned within a decade of harvesting.

The same general treatment is accorded fuelwood, except that it is assumed that fuelwood displaces conventional fossil fuels in fixed proportions, representing the average fossil fuel use mix for residential space heating. Thus, not of all the carbon that is released in fuelwood burning will be lost.[14] However, as in the case of other products that are burned, the accounting caries forward for only a single period, to reflect the fact that fuelwood must be used relatively quickly after harvest to be an effective source of space heating fuel.

Nonmerchantable Carbon

Nonmerchantable carbon, or woody debris, also decays after harvest. The decay rates vary by region, species, and decade. Data for modeling these decay rates were obtained from Harmon (1993). One problem in tracking the buildup and decay of woody debris is due to the fact that FASOM does not track stands, on an acreage basis, after harvest. Once a cohort is harvested in FASOM, the land on which that cohort resided is thrown into an undifferentiated pool of acres from which new acres can be drawn for regeneration purposes. Thus, if one assumes that all nonmerchantable carbon decays at the rates indicated in Harmon's data, there is a tendency for very large accumulations of carbon to develop in this pool. One way to deal with this problem is to truncate the number of periods over which the

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[13] For convenience, the first two categories were combined to reflect a single stored carbon pool, regardless of the life-cycle stage.

[14] The treatment of pulpwood as a fuel for co-generation is treated explicitly in HARVCARB in the same fashion

woody debris from any given cohort can accumulate. A truncation of 3 to 4 periods, tends to produce a terminal woody debris pool that converges on the size of the pool simulated by Turner et al. (1993).[15]

2.4.4 Old Growth Timber

Old growth timber represents a unique modeling challenge, with important policy ramifications. In the past, at least one Congressional Bill, the so-called Cooper-Synar Bill, allowed firms to receive CO_2 emission credits for planting trees and then maintaining them as old growth forests, past 100 years. The optimal age for rotating trees under a carbon sequestration objective is not a settled question by any means. However, if carbon decay rates are high, relative to carbon accumulation in growing trees, than this will create pressure to lengthen harvest rotations. Unfortunately, the growth and yield tables that are available, almost without exception, are for stands that are managed for timber supply (i.e., financial) objectives. They do not, as a rule, follow the growth of merchantable volumes in a stand much after a reasonable harvest age. Nor do they model the transition and climax of an old growth forest that is unmanaged for 100 to 300 years. This is also true for the carbon accounting conventions that are used by Birdsey and others.

The yield tables in FASOM assume a range of conventional timber management practices up to rotation ages that are reasonable from an economic and forest management perspective. The carbon that accumulates in the trees whose growth is simulated by FASOM is consistent with this type of growth. For FASOM to simulate the carbon and economic consequences of developing and preserving old growth or climax forests will require the development of accurate growth and yield tables, both for trees older than 90+ years and for stands (like unmanaged Douglas-fir) that may make the transition to a different climax species, if left unmanaged.

2.4.5 Public and Noncommercial Timber Carbon

The carbon from these sources is not included in FASOM due to a lack of inventory data.

2.5 DYNAMIC STRUCTURE

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[15] With a truncation of this length, carbon in woody debris accounts for about 8% to 12% of the total carbon by 2080, close to the 10% estimate obtained by Turner et al. (1993) in their simulations.

FASOM contains a number of important dynamic features involving the structure of, and linkages between, various parts of the land asset base within the model, the terminal conditions, and the objective function.

2.5.1 Dynamic Entities

There are four types of dynamic entities related to the land base within the model: 1) existing forest lands; 2) potentially reforestable lands; 3) agricultural lands; and 4) lands transferred between sectors. The model treats each of these differently.

Existing forested lands are held until they reach their endogenously determined harvest dates. They incur maintenance (tending) costs for all the years up to the harvest date. Once these stands reach harvest age, land is released for another use. The land may be either reforested or transferred to agriculture. This decision also embodies a number of dynamic dimensions. The potentially reforestable acres are balanced decade by decade with the land available from forest harvest and in-migration from agriculture. When land is reforested the model also selects another optimal future harvest date. These acres are then retained in the forest base until their harvest date at which time another reforestation-transfer decision is made.

The agricultural sector, unlike forestry, comprises a set of single "typical" year enterprises. The adoption of an activity by the model embodies the assumption that the land is used in that pattern throughout the decade. The same thing is done year after year, without direct implication for land use in the next decade. Thus, the agricultural activities are typical year activities. As a consequence the returns and costs are multiplied by a factor giving the value of returns if the pattern is followed in all 10 years.

Land transferred to and from agriculture is modeled under the assumption that when the land moves it changes the land base in all periods through the end of the projection period. Thus an acre transferring into agriculture in decade 2 also provides land in decades 3,4,...N. Similarly an acre transferring out will be removed from all future periods. This does not preclude land moving into agriculture for several periods then exiting.

2.5.2 Terminal Conditions

The model has three sets of terminal conditions. These apply to:

< The terminal inventory of private timberland

- Agricultural lands in the terminal period
- Stumpage processing capacity in the terminal period.

Timber inventory remaining at the end of a finite projection period should be incorporated in the objective at the value that would obtain if it were managed in an optimal fashion in perpetuity (from the terminal time point onward). If all possible terminal inventory states were valued in a such a fashion, the infinite horizon harvest problem would involve (in the spirit of Bellman's principle of optimality) choosing the optimal path from a fixed starting point (the current inventory) to one of the several terminal inventory states, so as to maximize the sum of transition and terminal values. Valuing, or approximating the value of, the terminal states would be aided if they could be characterized in some general way. If all external conditions are held constant after some point, available theoretical studies generally concur that convergence to some form of equilibrium (fixed cycles or even flow) is to be expected, but it is difficult to be more specific except in special cases.

If, as in the case of FASOM, policy concern is limited to the first few periods of the projection, a practical solution is to adopt some approximation for terminal inventory valuation and extend the projection period to the point where the discounted contribution of the terminal state is so small that it does not influence the results in the period of interest. This is the approach taken here. For any given terminal inventory volume, an associated perpetual periodic harvest volume is computed assuming the inventory is fully regulated. We used von Mantel's triangle formula simplification for this purpose. Rotation ages for this calculation were drawn from harvest ages observed in the FASOM solution in the decades prior to termination.[16] The value of this

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[16] The simplification (see Davis and Johnson, 1987) assumes a linear yield function so that in a forest fully regulated on a rotation of R years the annual harvest volume would be determined as twice the growing stock divided by the rotation age. A fully regulated forest has an equal number of acres in each age class from regeneration through the rotation age and can produce an even flow of volume in each year by harvesting just the oldest (rotation age) class. This "target" structure seems a reasonable terminal approximation. Our choice of rotation should approximate the so-called Faustmann rotation age, and there are numerous studies that demonstrate the optimality of the Faustmann rotation for a fully regulated, steady state forest in the long-run (e.g., Heaps, 1984; Brazee and Mendelsohn, 1988; Hellsten, 1988; and Lyon and Sedjo, 1983). As noted above, however, clear demonstration that an optimal harvest trajectory leads directly to full regulation of the forest on a Faustmann rotation in the long-run has proven elusive (see Mitra and Wan, 1985; 1986).

3.0 FASOM STRUCTURE AND TABLEAU

This section presents the programming structure of the model in two sections. The first deals with the overall formulation, detailing the forestry component with an highly simplified agricultural representation. The second concentrates on the agricultural component.

3.1 THE FASOM TABLEAU: FORESTRY COMPONENT

A tabular overview of the forestry component of FASOM *for a single region* is given in Table 3-1. The columns in this table represent variables, while the rows represent equations. The tableau has been simplified, so it can be included on a single page and still convey the basic structure and features of the model. The carbon sector is presented only in abbreviated form. The tableau does not portray external product trade (import/export) activities or constraints nor does it show the data computations that are made within the GAMS code. The reader interested in a more detailed version of the tableau can consult Appendix C, which contains a copy of the GAMS computer code for the current version of FASOM.

3.1.1 Variables

The tableau represented in Table 3-1 depicts four time periods: now (t=0), ten years from now (+10), twenty years from now (+20), and never. Management decisions are condensed into eight (8) types of non-negative variables. These appear as columns in the tableau. If the value of one of these variables is zero, information is provided that shows what it would cost society, in terms of the change in consumers' and producers' surplus, to force one unit of that activity into the objective function. This value is sometimes referred to as the "opportunity cost" of a variable. The variables are described briefly below and more fully in Section 3.3.

< Harvest Existing Lands, by harvest period:

  P Now (t=0)
  P 10 yrs. from now (+10)
  P 20 yrs. from now (+20)
  P Never.

Table 3-1. Sample Tableau for Overall FASOM Model Emphasizing Forestry Component

(Note: The coefficients below give the signs/values of the parameters in the model.)

		1				2					3			3			4			5			6			7			9		
		Harvest Existing Land				Reforest Now for Harvest			Reforest in +10 for Harvest in		Transfer Forest Land to Ag Use			Transfer Ag Land to Forest Use			Ag Land Use			Transport Forest Products			Sell Forest Products			Build Forest Process Capacity			Terminal Value		
Equations		Now	+10	+20	Never	+10	+20	Never	+20	Never	Now	+10	+20	Now	+10	+20	Now	+10	+20	Now	+10	+20	Now	+10	+20	Now	+10	+20	Timber	Capacity	RHS
Objective Fn.		-	-	-	-	-	-	-	-	-	-	-	-				+/-	+/-	+/-	-	-	-	+	+	+	-	-	-	+	+	
Existing Forest		+1	+1	+1	+1																										# +
Forest Products Supply	Now	-																		+1											# +
	+10		-			-															+1										# +
	+20			-			-		-													+1									# +
Forest Products Demand	Now																			-1			+1								# 0
	+10																				-1			+1							# 0
	+20																					-1			+1						# 0
Forest Products Capacity	Now																						+1			-					# +
	+10																							+1		-	-				# +
	+20																								+1	-	-	-			# +
	Now	-	-	-	-	-	-	-	-	-																					# 0
Carbon	+10	-	-	-	-	-	-	-	-	-																					# 0
Balance	+20	-	-	-	-	-	-	-	-	-																					# 0
Reforested Lands Balance	Now	-1				+1	+1	+1			+1			-1																	# -
	+10		-1			-1			+1	+1		+1			-1																# -
	+20			-1			-1			+1			+1			-1															# -
Ag Lands Balance	Now										-1			+1			+1														# +
	+10										-1	-1		+1	+1			+1													# +
	+20										-1	-1	-1	+1	+1	+1			+1												# +
Max Land Transfer	to Ag										+1	+1	+1																		# +
	to For													+1	+1	+1															# +
Terminal Balance	Timber				-1			-1		-1																			+1		# 0
	Capacity																									-	-	-		+1	# 0

< Reforest land with a harvest date, by planting period and harvest period:[17]

P Plant Now, harvest:

— 10 yrs. from now (+10)
— 20 yrs. from now (+20)
— Never.

P Plant 10 yrs From Now, harvest:

— 10 yrs. later (i.e., 20 yrs. from now)
— Never.

P Plant 20 years from Now, harvest:

— Never.

< Transfer Land, to/from Agriculture by period of transfer

P To Agriculture from Forests:

— Now
— 10 years from now (+10)
— 20 years from now (+20).

P From Agriculture to Forests:

— Now
— 10 years from now (+10)
— 20 years from now (+20).

< Use Agricultural Land by period:

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[17] The progression of variables, expressed here, is a function of the number of management periods. More generally, if there are t=1,...,N (1=Now and N=Never) harvest periods in the model, there would be k=1,...,N-1 planting periods. If the harvest interval is the same duration as the length of the planting period (e.g., 10 yrs.) then there will be N-1 broad planting periods harvesting periods, for a total of 2N = N-1 + N-2 + N-3 +... N-(N-1) variables or variables under this heading.

    P Now
    P 10 yrs. from now (+10)
    P 20 yrs. from now (+20).

< Transport forest product to demand by period:

    P Now
    P 10 yrs. from now (+10)
    P 20 yrs. from now (+20).

< Sell Forest Products by sale period:

    P Now
    P 10 yrs. from now (+10)
    P 20 yrs. from now (+20).

< Build Processing Capacity by period:

    P Now
    P 10 yrs. from now (+10)
    P 20 yrs. from now (+20).

< Value Terminal Inventory for:

    P Forest Sector
    P Forest Processing Capacity.

3.1.2 Equations

The reduced tableau in Table 3-1 contains twelve equations, including one nonlinear equation for the objective function and ten linear constraint equations. These equations are represented by the rows in the FASOM tableau in Table 3-1. The nonlinear portion of the objective function is not normally revealed in a standard tableau and is discussed in more detail, along with the rest of the constraints, in Section 3.4. Each of the ten constraints has an inequality direction associated with it and an indication of the sign of the associated right-hand-side (RHS) value. If the variables in the model fully utilize all of the resource on the RHS of a specific constraint, then there will be a shadow price on this constraint. This shadow price indicates the change in the objective function resulting from an increase in the RHS of the constraint by one unit.

The following constraints are included in the model:

- Existing Land Balance
- Forest Products Supply Balance by period:
  - Now
  - 10 yrs. from now (+10)
  - 20 yrs. from now (+20).
- Forest Products Demand Balance by period:
  - Now
  - 10 yrs. from now (+10)
  - 20 yrs. from now (+20).
- Forest Processing Capacity by period:
  - Now
  - 10 yrs. from now (+10)
  - 20 yrs. from now (+20).
- Carbon Balances by period:
  - Now
  - 10 yrs. from now (+10)
  - 20 yrs. from now (+20)
  - Terminal period.
- Reforested Land Balance by period:
  - Now
  - 10 yrs. from now (+10)
  - 20 yrs. from now (+20).
- Agricultural Land Balance by period:
  - Now
  - 10 yrs. from now (+10)

P 20 yrs. from now (+20).

< Maximum Land that can Transfer:

  P To Ag
  P To Forestry.

< Terminal Balances:

  P Terminal Forest Processing Capacity
  P Terminal Forest Inventory.

3.1.3 Variables

The columns in the tableau represent variables in FASOM. The order in which the variables are described in the sections below is shown numerically above each column. For example, the discussion of the variable(s) characterizing the building of mill capacity (Build Milling Capacity) is shown discussed in Section 3.1.3.7, as indicated by the number seven (7) above the tableau columns.

3.1.3.1 Harvest Existing Lands

The model includes the decision of when to harvest stands that are in the private timberland inventory at the start of the projection. These lands are grouped by region, agricultural suitability class and immediate past use, type of owner, site quality, age cohort, species and immediate past species, management regime, and time of harvest. The tableau illustrates these variables for harvests that take place in the current period ("now"), in +10 and +20 years, and "never". In the full model, the time of harvest can range from the current period to 90 years from now, or never. This variable appears in the FASOM NLP formulation with:

< A negative objective function coefficient, reflecting the net present value of all management and harvesting costs from now to the time of harvest

< A positive one in the existing inventory row, reflecting use[18] (harvest) of an acre

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[18] The term "use" in connection with a variable means that the variable uses some of the resource in the constraint equation allotted to that resource. The amount of use is indicated by the symbol in the tableau, where a +1 means a 1:1 use and a + sign implies that the ratio of use to resource availability is less than or greater than 1. For example, in Table 3-1, there is a one (1) under each variable called "Harvest Existing" (e.g., forests) in the row called "Existing Land". This means that 1 unit of land is taken from the right-hand-side of the existing land row for each acre harvested.

- A negative entry in the supply row for wood products, reflecting the yield of products including the simultaneous production mixture of softwood and hardwood sawlogs, pulpwood, and fuelwood in the decade when the land is harvested
- A negative entry in the carbon balance row which accounts for yield of carbon before and after harvest, including the carbon remaining in products in decades after the stand is harvested
- A negative one in the reforested land balance row, which can be reforested or transferred in the decade where the harvesting occurs
- A negative one in the terminal balance row, indicating the volume of wood on unharvested acres at the end of the projection period.

3.1.3.2 Reforest Land and Harvest

FASOM simulates the decision of reforesting previously harvested lands or afforesting lands transferred from agriculture. These lands are grouped by region, agricultural suitability and immediately prior land use class, owner, site quality, management regime, species and immediately prior species, decade when the stand is established, and time of harvest for the new stand. Time of harvest can range from the current period to 90 years from now, or never. This variable appears in the FASOM NLP formulation with:

- A negative entry in the objective function, reflecting the present value of the establishment, maintenance and harvest cost of a stand over its life
- A negative entry in the forest products supply row giving the yield of wood products in the decade of harvest, which includes sawlogs, pulpwood, and fuelwood
- A negative entry in the carbon balance row giving the supply of carbon in the relevant model decades, which includes carbon before and after harvest, including the carbon remaining in products in decades after the stand is harvested
- A positive one in the appropriate reforested land balance row, indicating the use of an acre of land in the decade when the stand is established

- A negative one in the appropriate reforested land balance row, indicating release of land for forestry or agricultural uses, including reforestation in the decade when the harvesting occurs

- A negative one in the terminal value row, reflecting the volume of unharvested wood at the end of the projection period.

3.1.3.3 Transfer Land to/from Agriculture

The model allows land to be transferred to agriculture rather than being reforested. Harvested timberland and regenerated timberland in the lowest management intensity class can be transferred to cropland or pasture land class categories. Transfers are grouped by region, land class, type of owner, cover type, site quality, age cohort of existing trees, management regime, and decade when the timberland is transferred. This variable appears in the FASOM NLP formulation with:

- A negative entry in the objective function, equalling the net present value of converting the land to agricultural production

- A positive one in the reforested lands balance row, indicating use of an acre of land in the decade in which the transfer took place

- A negative one in the ag lands balance row, indicating supply of land for agricultural use in the decade when the transfer occurs and in all future decades

- A positive one in the maximum land transfer constraint.

The model also depicts the decision of transferring land from agriculture to forestry. The shift is allowed only for lands that are in the cropland or pasture land class categories and accounts for transfers by region, land class, type of owner, and site quality. This variable appears in the FASOM NLP formulation with:

- A zero in the objective function since the "conversion" costs are incorporated in the establishment cost portion of the timber management budgets

- A negative one in the reforested land balance row, indicating supply of land that can be forested in the decade when the land is transferred

< A positive one in the land available row, indicating withdrawal of the land from agricultural use in the decade when the transfer occurs and all subsequent decades.

< A positive one in the maximum land transfer constraint.

3.1.3.4 Agricultural Land Use

This activity and the row labeled "Ag Land Balance" represent the highly simplified ASM model in this tableau. FASOM includes all the production, factor supply, demand, processing, crop mix and farm program features of ASM. These features are explained in the next section.

< Both positive and negative coefficients in the objective function, indicating the net present value of the agricultural portions of ASM. These terms include the integration of areas under the agricultural supply and demand curves. The coefficients in the last period are multiplied by a factor converting them to an infinite stream providing terminal conditions on land in agriculture.

< A set of positive ones in the agricultural land rows in the decade when the land is used

< A number of other constraint entries (not shown in the tableau) to depict linkages between agricultural production and processing, obeyance of crop mix restrictions, etc.

3.1.3.5 Forest Product Transport to Demand

The model simulates transport of forest products between domestic regions and foreign trade regions. Flows of products are grouped by region of origin, product type, and decade. This variable appears in the FASOM NLP formulation with:

< A negative entry in the objective function and import source supply, reflecting the net present value of transporting the good

< A positive one in the forest products supply rows, indicating use of a unit of the good in the area of origin during the decade of transport

< A negative one in the national forest product demand or export equations, indicating supply of a unit of the good for consumption during the decade of transport.

3.1.3.6 Forest Products Sale

The sale of products is depicted for both domestic and international transaction by decade. The variables are defined for sawlogs, pulpwood, and fuelwood from both hardwood or softwood sources.

The model accounts for the value of forest products sold by integration under the forest products demand curves. This variable appears in the FASOM NLP formulation with:

- A positive entry in the objective function which is the net present value of the integral of the area under the forest product demand curves
- A positive one in the forest product demand rows, indicating use of one unit of the relevant forest product.
- A positive one in the forest product capacity row.

3.1.3.7 Build Forest Products Processing Capacity

The model determines whether the forest product processing capacity is adequate or whether additional capacity needs to be constructed. This variable appears in the FASOM NLP formulation with:

- A negative entry in the objective function which reflects the net present value of the cost of capacity construction
- A negative entry in the forest products capacity row, reflecting the supply of capacity in this and all future decades, where all capacity increments are adjusted for depreciation in future decades
- A negative entry giving the supply of depreciated capacity in the terminal capacity row.

3.1.3.8 Forest Products Imports/Exports

Although these variables are not shown in Table 3-1, the optimal import and export of products is depicted by international trade possibilities by decade arising when sawlogs, and pulpwood are traded, differentiated by hardwood or softwood sources. The model accounts for the costs and returns from forest products trade by integration under the forest product import supply and export demand curves. These variables appear in the FASOM NLP formulation with:

- A negative entry in the objective function, reflecting the net present value of the integral of the area under the forest product import supply curves or a positive entry for the integral under the export demand equation

- A negative one in the imported quantity row, depicting supply of one unit of the relevant forest product import

- A positive one in the exported quantity row, depicting use of one unit of the relevant forest product for export.

3.1.3.9 Terminal Value of Unharvested Forest Stands and Processing Capacity

The model values unharvested stands at the end of the projection period by means of the final decade demand curve. The quantities valued are differentiated by age, region, land class, type of owner, site quality, management regime, and whether the trees are from an original or reestablished stand. As previously indicated, agricultural returns and costs in the next-to-last decade are multiplied by a factor treating them as an infinite stream. Capacity is valued at its development cost. This variable appears in the FASOM NLP formulation with:

- A positive entry in the objective function, equalling the net present value of the area under the standing forest terminal value demand curve minus management costs or the replacement cost of a unit of capacity

- Positive one in the terminal value row, indicating use of either: a) an acre from the terminal inventory accounting rows, or b) a unit from the terminal capacity row.

3.1.4 Model Equations

The model equations are represented by the rows of the tableau. The order in which the equations are described below is the same as in the tableau.

3.1.4.1 Objective Function

The FASOM objective function depicts maximization of the net present value of producers' and consumers' surplus. As such it is a technical device which simulates production and price formation in competitive markets over time for both agricultural and forest products. In that sense, the first-order (Kuhn-Tucker) conditions for the choice variables in the model provide a set of rules for economic agents to follow, leading to the establishment of a competitive equilibrium.

The objective function contains a nonlinear portion, which represents the area under the demand curves for agricultural and forest products. In FASOM, demand for agricultural products is characterized by constant elasticity demand functions, while demand for forest products is characterized by linear functions. The linear portion of the objective function includes the costs associated with producing, managing, harvesting and selling agricultural and forest products in the various regions in the model. This equation appears in the FASOM NLP formulation with terms for each type of variable for each decade, weighted by the discount rate as follows:

- A negative entry for the Harvest Existing Lands variable, reflecting the net present value of all costs which are incurred in managing and, if relevant, harvesting a stand

- A negative entry for the Reforest and Harvest a New Forest Stand variable, reflecting the present value of the costs of establishing, maintaining and, if relevant, harvesting the stand

- A negative entry for the Transferring Land to Agriculture variables, reflecting the net present value of the cost of preparing the land for agricultural production

- No entry in the objective function for the Transfer Land from Agriculture variables as the costs are assumed present in the establishment cost part of the reforestation budgets

- Positive and negative entries for the Agricultural Land Use variable giving the net present value of the agricultural portions of the model. Some of these terms include the integration of areas under the agricultural supply and demand curves. The entries of the last period are multiplied by a constant converting them to an infinite stream.

- A negative entry for the Forest Product Transport variables, reflecting the net present value of transportation costs for the forest products

- A positive entry for the Forest Products Sale variables giving the net present value of the integral of the area under the forest product demand curve

- A negative entry for the Build Capacity variable, reflecting the cost of building additional forest processing capacity

- A positive entry for the Terminal Valuation variables, equaling the net future value for unharvested stands, and forest product processing capacity in the final model decade.

- A negative entry for the Forest Products Import variables, reflecting the net present value of the integral of the area under the forest imports curve.

3.1.4.2 Existing Forested Lands Balance

The model has constraints which restrict the use of currently forested lands to those that are available. The restriction is only defined for stands in existence in the initial model decade. The restriction accounts for the inventory by region, land class, type of owner, cover type, site quality, and age cohort. This constant appears in the FASOM NLP formulation with:

- A positive one under the Harvest Existing Forested lands variables, depicting usage of an acre

- A positive entry giving the existing forest inventory on the RHS.

3.1.4.3 Forest Products (Supply) Balance

The model has a constraint which restricts sale of forest products to those that are produced. The restriction is defined for all model decades. The restriction accounts for sawlogs, pulpwood and fuelwood products both from hardwood and softwood sources on a regional basis. This constraint appears in the FASOM NLP formulation with:

- A negative entry under the Harvest Existing Forested Lands variables which depicts the yield of harvested products in the relevant decade

- A negative entry under the Reforest and Harvest variables, which depict supply of harvested products in the relevant decade

- A positive one under the Market Transport variables, indicating withdrawal of a unit of the good from the area of origin during the decade of transport

- A positive entry on the RHS, depicting supply of products from public lands as well as any other exogenous supply.

3.1.4.4 Forest Products (Demand) Balance

The model has constraints which ensure that the sum of all shipments to domestic destinations is equivalent to total demand. These constraints are defined for each product and decade in the projection. The constraints appear with:

- A negative one under the Transport Forest Products variables indicating movement of one unit of the good into national demand from the area of origin during the decade of transport
- A positive one in the Sell Forest Products variables, indicating use of one unit in meeting demand
- A zero RHS value, indicating that demand levels can be no larger than the volumes shipped.

3.1.4.5 Forest Processing Capacity

The model has a constraint which accounts for capacity utilization verses capacity supply. This constraint appears in the FASOM NLP with:

- A positive one under the domestic Sell Forest Products variables, indicating capacity utilization
- A negative entry under the Build Capacity variables which reflect the addition of capacity in the year added and the addition of depreciated capacity in subsequent years
- A positive entry on the RHS, reflecting the depreciated availability of initial capacity by decade.

3.1.4.6 Carbon Balance

The model has a constraint which accounts for carbon sequestered in the forest by decade. The relation is defined for all model decades. Pre- and post- harvest carbon are accumulated. The calculations account for the increase in sequestration from existing unharvested stands in the merchantable and unmerchantable portions of the tree and in the soil, understory, and forest floor, accounting for the harvest losses and fate of carbon over time in both forest products and woody debris. The restriction accounts for carbon by decade on a national basis. This equation appears in the FASOM NLP formulation with:

- A negative entry under the Harvest Existing Forested Lands variables, which depict carbon in standing timber and carbon fate after harvest in all decades

- A negative entry under the Reforest and Afforest Lands variables, which depicts carbon in standing timber and carbon fate after harvest in all decades after establishment

- A positive entry under the Agricultural Production variables (not shown in Table 3-1) giving the amount of soil carbon on agricultural lands

- Zero RHS values. Alternatively, provisions can be made to include a set of "buy carbon" variables in FASOM with a positive carbon price or downward sloping demand curves for carbon and these variables would take carbon from this set of equations and transfer it to the sell carbon activity. This would allow the user to model subsidy programs and even the marginal social benefits of carbon (in the demand curve framework). These alternatives avoid the need to force carbon quantities into the optimal solution and replace it with a dual[19] approach, and will be incorporated in model experiments and policy analyses.

3.1.4.7 Reforested Lands Balance

The model has a constraint restricting the use of land which potentially could be reforested or afforested to those lands released by harvesting adjusted for agricultural transfers. (These transfers include conversions to urban/developed uses are reflected in the constraints, with a certain percentage of timber volumes on converted lands contributing to timber harvest). The restriction is defined in each model decade. The restriction accounts for land by region, land class, type of owner, and site characteristic. This constraint appears in the FASOM NLP formulation with:

- A negative one under the Harvest Existing Forested Lands variables, which depict release of an acre after harvest for potential reforestation

- A positive one under the Reforest Lands variables, which depict use of land in the relevant decade

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[19] The term dual refers to the fact that the shadow price associated with a given quantity of carbon on the RHS of this equation can be used as the price of an activity that replaces the RHS value (such as a "buy carbon" activity), resulting in a model solution that will yield the same carbon value (quantity) as on the original RHS.

- A negative one under the Harvest Reforested Lands variables, which depict supply of land for subsequent reforestation in the relevant decade

- A positive one under the Transfer Land to Agriculture variables, which depict flow of land from forestry to agriculture in the relevant decade

- A negative one under the Transfer Land from Agriculture variables, which depict supply of additional land into the forestry sector in the relevant decade

- A set of negative RHS values to reflect the transfer of land to urban encroachment and the transformation of the new lands into forestry.

3.1.4.8 Agricultural Lands Balance

The model has a constraint set which balances land flowing to and from agriculture. The restriction is defined by model decade. The restriction accounts for land by region, and land class. This constraint appears in the FASOM NLP formulation with:

- A negative one under the Transfer Land to Agriculture variables which depicts an incoming flow of land into the agricultural sector in the decade it transfers and all subsequent decades

- A positive one under the Transfer Land from Agriculture variables, which depict land flowing out to forestry in the decade it transfers and all subsequent decades

- Positive and negative entries under the Agricultural Land Use variables (not fully shown in the sample tableau) which depict land use and supply considerations in ASM by decade

- Positive RHS values.

3.1.4.9 Maximum Land That Can Transfer

The model limits the amount of land that can transfer between sectors over the entire model time horizon. These constraints are defined for each sector and region. The constraints have:

- A positive one under the land transfer variable summed across all the decades

- A positive RHS giving the amount of land that can transfer.

3.1.4.10 Terminal Unharvested Forest Stand Balance

The model accounts for unharvested stands at the end of the explicit model time horizon. Quantities are accounted by cohort, region, land class, type of owner, site quality, management regime, and whether the trees are from an original or reestablished stand. This constraint appears in the FASOM NLP formulation with:

- A negative one under the Harvest Existing Lands variables which depicts supply of the volume of timber left unharvested after the model time frame
- A negative one under the Reforest and Harvest a New Forest Stand variables which reflect the volume of reestablished stands which are not harvested during the explicit model time horizon
- A positive one under the Terminal Value variables which reflect use of unharvested inventory in assigning a value to future use of unharvested stands
- Zero RHS value.

3.1.4.11 Terminal Capacity

The model accounts for the future value of undepreciated processing capacity after the model times horizon with terminal conditions. These equations have:

- A negative entry under the Build Capacity variables, reflecting undepreciated capacity
- A positive one under the Terminal Value variables, reflecting capacity use when contracting terminal valuation.
- Zero RHS value.

3.1.4.12 Constraints Not Shown in the Sample Tableau

To simplify the sample tableau some classes of constraints were deleted because they are of lesser overall importance in the functioning of the forest sector. These constraints include:

Forest Imports/Exports

The model has constraints which balance the transportation of imported and exported forestry product with the forest products imported and exported. These constraints appear in the FASOM NLP formulation with:

- A positive entry under the Import Transportation variable, which reflect a movement of a unit of goods from imports into one of the demand markets
- A negative entry under the Import Supply variable, which reflects the supply of a unit from imports
- A negative entry under the Export Transportation variables which reflect a movement of goods from one of the supply areas to export.

Agricultural Resource Balances

The model has several constraint sets which restrict agricultural activity as explained in the following discussion.

3.2 THE FASOM TABLEAU-AGRICULTURAL COMPONENT

Table 3-2 presents an overview of the agricultural part of FASOM. This details the agricultural variables and resource constraints in Table 3-1. Table 3-2 portrays the tableau for one typical time period and one regional dimension. The columns in this tableau represent variables, in the FASOM model, while the rows represent constraints. The tableau has been simplified so it fits on a single page and still conveys some of the basic structure and features of the model. Also the tableau does not include computations within the GAMS code. The reader who is interested in looking at more details can turn to Appendix C, which contains a copy of the GAMS computer code for the current version of FASOM.

3.2.1 Variables

The Agricultural model contains 19 types of variables. The first three variable sets have already been explained in the forestry section above. The others are particular to agriculture. Briefly these variables are:

- Forestry Variables - those detailed in Table 3-1
- Transfer Land from Forest - transfers of land from forest to agricultural use
- Transfer Land to Forest - transfers of agricultural crop or pasture land to forest
- Program Crop Production - production of cropped acreage which is participating in the farm program
- Nonprogram Crop Production - production of cropped acreage not covered under the farm program and/or not participating in the farm program
- Livestock Production - production of livestock
- Crop Mix - acreage in historically observed crop mixes by region
- Livestock Mix - a number of historically observed national distributions of selected livestock commodities

Table 3-2. Sample Tableau for Agricultural Component of FASOM

Equation	Program Crop Production	Non-program Crop Production	Livestock Production	Crop Mix	Livestock Mix	Land Supply	AUM Supply	Water Supply	Labor Supply	Input Purchase	Process	Demand	Export Demand	Import Supply	CCC Loan	Deficiency Payment	Other FP Payments	RHS
Objective	-	-	-			-	-	-	-	-	-	+	+	-	+	+	+	
Crop Land	+	+1				-1												# 0
Max Crop						+1												# +
Pasture Land			+			-1												# 0
Max Pasture						+1												# +
AUM Grazing			+				-1											# 0
Max Pub AUM							+1											# +
Water	+	+	+					-1										# 0
Fixed Water								+1										# +
Labor	+	+	+						-1									# 0
Family Labor									+1									# +
Ag Inputs	+	+	+							-1	+							# 0
Primary Products	-	-	+/-								+/-	+1	+1	-1	+1	-1		# 0
Secondary Products			+								+/-	+1	+1	-1	+1			# 0
Farm Program Products	-															+1		# 0
Other Farm Programs	-																+1	# 0
Crop Mix	+1	+1		-														= 0
Livestock Mix			+		-													= 0

< Land Supply - supply of pasture, crop, and AUM (animal unit month) land available according to supply curves

< Water Supply - supply of irrigation water including fixed price and pumped water components according to supply curves

< Labor supply - supply of family and hired labor according to supply curves

< Input Purchase - use of a set of fixed price inputs

< Processing - quantity of primary commodities processed into secondary agricultural products

< Domestic Demand - quantity of domestic consumption for primary and secondary products according to demand curves

< Export Demand - quantity exported of primary and secondary commodities according to excess demand curves

< Import Supply - amount of imports of primary and secondary commodities according to excess supply curves

< CCC Loan - government purchases of some primary and secondary commodities under the CCC Loan program

< Deficiency Payment - payment of deficiency payment to farm program eligible participating commodities

< Other Farm Program Payments - 50/92, paid acres, diverted acres, and other program payments where agriculture gets payments for commodities not being produced.

3.2.2 Equations

There are 19 equations in the model. These include the objective function and 18 constraints. The constraints are as follows:

< Forestry Land - reflects the set of forestry constraints covered under the Table 3-1 discussion

- Cropland - balances land available for crops with land supplied while accounting for the migration of land in and out of agriculture

- Maximum Cropland - Limits the maximum amount of cropland that can be in use at any time

- Pasture Land - balances the supply of pasture land against livestock use of pasture while accounting for land transferring in and out of agriculture

- Maximum Pasture Land - imposes a limit on the maximum amount of pasture land

- AUM Grazing Land - balances the supply of AUM grazing from public and private sources with the use of AUMs in livestock rearing

- Maximum Public AUMs - imposes a limit on the maximum AUMs of public grazing

- Water - balances irrigation water supply with the water utilized in crop and possibly livestock production

- Fixed Water Maximum - limits the maximum amount of fixed price water

- Labor - balances labor used in production with total labor supply including both family and hired labor

- Maximum Family Labor - imposes a maximum on the family labor available

- Agricultural Inputs - balances the supply of agricultural inputs with the use by processing crop and livestock production

- Primary Products - balances primary products supplied and consumed. The primary products are supplied by crop and livestock production or imports. They can be consumed in livestock production, processing market demand, or export variables.

- Secondary Commodities - balances the secondary commodities supplied and demanded

- Farm Program Products - balances participating production with that receiving deficiency payments

- Other Farm Program Provisions - balances the supply of diverted production eligible for farm program payments with the commodities for which payments are made

- Crop Mix - constrains crops to fall in their regional historical acreage

- Livestock Mix - constrains livestock commodities to fall within their national historical distribution.

3.2.3 Variables

The agricultural variables are defined in more detail below, including some variables not mentioned in Table 3-2. A full list of all these variables appears in the GAMS model. Also, the first three variables listed in Section 3.2.1 will be omitted as those have already been discussed in the forestry section above.

3.2.3.1 Program Crop Production

Crops can be produced inside or outside the farm program context. The model depicts participating farm program crop production differentiated by decade, region, type of crop, water technology (dryland or irrigated) and conceivably crop technology. These variables appear in the FASOM NLP with:

- A negative entry in the objective function giving per acre cost of miscellaneous inputs plus nominal profits

- A positive entry in the land balance giving cropland use. The quantity recorded includes both the use of an acre that is harvested plus the use of any acreage which must be set aside or diverted.

- A positive entry in the water row giving the use of irrigation water for production variables which are irrigated

- A positive entry in the labor row giving the use of labor for crop production

- A positive entry in the input balance row giving the use of inputs for production

< A negative entry in the primary balance row, reflecting the production of primary products. The coefficient here only equals the amount not eligible for deficiency payments which equals that produced from land not participating in the farm program plus the amount produced in excess of the farm program yield.

< A positive entry in the secondary balance constraint giving the use of secondary products in production; in general this is zero

< A negative entry in farm program yield balance equation giving yield eligible for deficiency payments. The coefficient equals the amount of the crop produced eligible for deficiency payments times the participating acreage.

< A negative entry in the 50/92 yield row giving the foregone yield quantity incurred by participation in the 50/92 program. Note this is not actual yield but is "foregone."

< A negative entry in the paid diversion row giving the amount of foregone yield eligible for diversion payments due to the participation in the paid diversion program

< A negative entry in the unharvested production rows giving the production foregone because it is left unharvested but is eligible for deficiency payments

< A negative entry in the artificial yield row which reflects the yield in cases when the actual yield is below the farm program yield, reflecting deficiency payments on crops that are not grown

< A positive one in the regional crop mix equation and a negative one in the regional total crop mix equation showing the number of harvested acres of this crop

< Upper or lower bounds when relevant.

3.2.3.2 Nonprogram Crop Production

This variable is essentially identical to the farm program production variable above. The differences are that the land use is only one acre, that the production occurs only in the primary balance row and that there are no entries for program deficiency payment, 50/92, etc. rows. These variables have the same dimensions as above and are defined both for nonprogram crops and for nonparticipating acreage of program crops.

3.2.3.3 Livestock Production

The model solves for the number of livestock reared. Livestock are depicted as users of land labor and feedstuffs while producing both final products (i.e., animals for slaughter) and intermediate products (i.e., calves for feeding). These variables are defined by decade, region, type of animal, and livestock technology choice. The variables reflect production of multiple products. The variables enter the model formulation with:

- A negative entry in the objective function giving the miscellaneous costs and profits for the livestock production activity

- A positive entry in the land use balance giving the use of crop and pasture land; usually this is confined to pasture land

- A positive entry in the AUM use balance giving the use of AUMS in livestock production

- A positive entry in the water row when there is water use for irrigated pasture

- A positive entry in the labor row giving labor use for production

- A positive entry in the input balance giving agricultural input use

- Both negative and positive entries in the primary balances, reflecting production and the use of primary agricultural products. Some commodities i.e., hogs produced, feeder pigs, cull sows, will only be produced appearing with negative signs while use of feedstuffs such as corn and soybeans will appear with positive coefficients.

- A positive entry in the secondary balances, reflecting the use of some secondary commodities in livestock production. In particular, feed and soybean meal are used for feedstuffs.

- A positive entry in the national livestock mix row controlling the production of commodities so it is consistent with the national commodity mixes

- Upper and lower bounds when present.

3.2.3.4 Regional Crop Mixes

The regional crop mix variables are equal the acres produced under each of the historical observed cropping patterns. Collectively, their presence restrains harvested crop acreage to fall somewhere in the historical observations. These variables are defined by region, decade, and for the historical observations in the model. Currently, these consist of about a twenty year series. These variables help resolve the aggregation problem as explained in McCarl et al. (1993). There could be some concern in using the crop mixes for all years and thus they are dropped after the first 20 years. These variables enter the model with:

< A negative entry in the crop mix by crop rows giving the amount of the commodity in the crop mix

< A negative entry in the total crop mix row giving the sum of the acreage in the crop mix.

3.2.3.5 National Mix

The national mix variables give the amount of commodity by region in each historically observed production pattern. The variables require that the spread of production of selected commodities among the regions being consistent with historical national mixes for that commodity. These variables are defined by decade, for a particular commodity and then historical alternatives. They are also dropped after the first 20 years. These variables have:

< A negative entry in the national mix rows giving the number of units of the commodity produced in a given model region.

3.2.3.6 Agricultural Land Supply

The land supply variables reflect the provision of pasture land, cropland, and AUM grazing land according to the specified supply curve. These variables are defined by decade, region, and land type. The variables enters the model with:

< A negative entry in the objective function giving the integral of the area underneath the land supply curve depicting as a cost of using land

< A negative one in the land supply balance, indicating supply of land

< A positive one in the maximum constraint on land availability.

3.2.3.7 Public AUM Grazing Supply

Animal unit months (AUMs) of grazing are supplied via a two part structure. The first part refers to the State and federal supplies through such agencies as the Bureau of Land Management and Forest Service. This land is available at a fixed rental rate up to a maximum. The public grazing variable enters the model with 3 coefficients. They are

- A negative entry in the objective function giving the cost of public grazing
- A negative one in the AUM grazing balance, reflecting the supply of public grazing
- A positive one in the public grazing limit row.

3.2.3.8 Private AUM Grazing Supply

Animal unit months of grazing are also supplied from private sources via a supply curve. These variables enter the model with:

- A negative entry in the objective function giving the area under the private grazing supply curve
- A negative one in the AUMS grazing balance, indicating supply
- Upper bounds on total private grazing availability.

3.2.3.9 Variable Price Water Supply

The model depicts supply of both fixed price water and variable price pumped water. The variable price water supply indicates more can be pumped at successively higher prices. The quantity that is pumped depicts both groundwater and the use of certain surface water. The variable price water supplies are defined by decade and region. This variable enters the model with:

- A negative entry in the objective function giving the integral of the area underneath the water supply curve
- A negative one in the water balance to indicate a supply of water.

3.2.3.10 Fixed Price Water Supply

The counterpart to the variable price water variable above is the fixed price water variable. The fixed price water is available at a fixed price up to a quantity upper limit. This situation reflects publicly owned surface water which is sold to farmers at a fixed price up to the quantity that they have been allocated. This variable is defined by decade and region and enters the model with:

- A negative entry appears in the objective function, reflecting the price of the fixed water variables
- A negative one in the water balance, indicating supply of water
- A positive one in the fixed price water maximum drawing on the fixed price water availability.

3.2.3.11 Hired Labor Supply

Labor supply is defined in an analogous fashion to the water supply above. There is a supply of family labor at a fixed price and then a supply of hired labor according to a supply schedule. The hired labor activity depicts that supply schedule and reflects a successively higher wage rate as more labor that is hired. This is defined by decade and by region. The variable enters the model with:

- A negative entry in the objective function giving the area underneath the hired labor supply schedule
- A negative one in the labor balance, reflecting supply.

3.2.3.12 Family Labor Supply

The second part of the labor supply is family labor which is made available at a lower price than the hired labor wage rate and is available up to a fixed quantity. The family labor variable enters the model as follows:

- A negative entry in the objective function giving the cost of family labor
- A negative one in the labor balance, indicating supply

- A positive one in the family labor limit row drawing against the maximum amount of family labor that is available.

3.2.3.13 National Input Supply

The national input supply variables depict the supply of inputs with assured constant prices and are defined by decade and input. The inputs are listed in the scope of ASM appendix. The variables enter the model with:

- A negative entry in the objective function giving the price of the input is reflected

- A negative one in the input balance, reflecting supply of the input is entered.

3.2.3.14 Processing

The processing variables reflect the transformation of primary agricultural products into one or more secondary products and are defined by decade and processing alternative. In the model, these variables include feed mixing, corn sweetener manufacturer, sugar refining, soybean crushing, livestock slaughter, etc. as listed in Appendix A. These variables enter the model with:

- A negative entry in the objective function giving the costs and profit considerations of processing

- A positive entry on the input balances giving the processing usage of agricultural inputs

- A positive entry in the primary commodity balance, reflecting use of primary commodities in processing. Negative entries are also possible when primary commodities are supplied by processing.

- A negative production of secondary commodities. Positive entries are also possible when secondary commodities are used as inputs in processing. This structure can be somewhat complex. For example, confectioneries are produced by a processing activity but also use the secondary commodity refined sugar.

- Maximum and minimum bounds on processing.

3.2.3.15 Domestic Demand for Primary Commodities

Primary products can be used in domestic demand. Such demand is defined for decade and for each of the primary commodities which have nonzero demand. The variables enter the model with:

- A positive entry in the objective function giving the area underneath the demand curve for the commodity. This can involve a price elastic curve, a perfectly elastic demand curve (if a fixed price is involved) or no entry if a minimum is all that is involved.
- A positive one in the primary balance, indicating a demand
- Upper and lower limits on the maximum quantity demanded.

3.2.3.16 Primary Exports Demand

A number of primary commodities are exported. The export variables indicate the quantity of such exports and are entered in much the same format as the domestic demand equations where the variable is defined for each decade and primary commodity. The variables contain the following:

- A positive entry in the objective function giving the area under the export demand curve
- A positive one the primary commodity balance, indicating a use of the commodity
- Upper and lower bounds on the quantity exported.

3.2.3.17 Primary Imports Supply

Selected primary commodities can be imported. These variables indicate the imports of primary commodities for each primary commodity and decade. The variables enter the model with:

- A negative entry in the objective function giving the area under the import supply equations
- A negative one in the primary commodity balance, indicating a supply of a commodity
- Bounds giving the maximum and minimum quantity that can be imported.

3.2.3.18 Secondary Commodity Demand, Imports and Exports

These variables depict the demand imports and exports for processed commodities (see list in Appendix A) and are identical in concept to the three immediately discussed above. They have:

- Objective function coefficients that reflect the area underneath their respective curves with the area being positive for domestic demand and exports and negative for imports

- Entries of positive ones in the secondary commodities balance row under the domestic demand and export variables minus ones present for import supply
- Upper and lower bounds.

3.2.3.19 CCC Loan Purchase

The Commodity Credit Corporation acquisitions of commodities put under loan are reflected in the CCC Loan purchase variables. Commodities placed under loan are removed from the marketplace and are assumed to be disposed in some nonmarket distorting use. These variables are defined by decade and eligible commodity. The model user has the ability to eliminate the farm program from particular decades and it is currently dropped after the first decade. These variables enter the model with:

- A positive entry in the objective function giving the price of the commodity as paid under the loan is entered as a revenue
- A positive one in the primary or secondary balance for eligible commodities, indicating use of a unit of the commodity.

3.2.3.20 Deficiency Payments

The deficiency payment variable gives the amount of crops receiving deficiency payments. This is present for the decades and primary commodities which receive such payments. This payment is varied through iteration to make sure that the difference between the market price and the target price is equal to the deficiency payment. These variables enter the model as follows:

- A positive entry enters the objective function reflects the deficiency payment as revenue; this coefficient is iterated over to obtain convergence on deficiency payments
- A negative one in the primary commodity balance, indicating a supply of commodity appears
- A positive one in the farm program commodity, indicating commodity use appears balance.

The variable transfers the commodity from a row accounting for goods eligible for deficiencies payments to the market row and reflects receipt of the deficiency payment. This causes the market price to be less than or equal to the farm program price.

3.2.3.21 Miscellaneous Farm Program Payments

These variables reflect government payments for farm program provisions involving 50/92, diverted acres unharvested production, and production below farm program yield. The model does not reflect an actual commodity produced under these features as acreage is diverted from production and farmers are paid for foregone production. These are defined for each decade and commodity that the farm program is active in. These variables enter the model with:

< A positive objective function coefficient equaling the deficiency or diversion payment found during the iterations

< A positive one in the relevant farm program balance equation, reflecting use of diverted production under the farm program provisions is entered.

3.2.3.22 Tolerance Allowing Variables

Tolerance variables are entered to avoid both infeasibility and cycling when dealing with the crop and national mixes. They allow small deviations from these mixes. These are defined for each decade, crop, and region for the regional crop mixes and by commodity, decade and region for the national crop mixes.

3.2.4 Model Equations

The agricultural component of the model equations also merit discussion. Here, we will skip the forestry parts of the tableau and concentrate on the agricultural parts including the agricultural component of the objective function.

3.2.4.1 The Objective Function - Agricultural Component

The agricultural objective function is weighted by a factor which reflects the fact that agricultural products are harvested each year during a decade. This factor equals the sum of the present value factors over 10 years. Furthermore the last decade is weighted by a factor equalling the future value of an infinite stream thereby supplying the terminal conditioning for land remaining in agriculture.

The basic objective function components include the discounted area underneath the downstream export demand curves for the commodities; plus the deficiency and other farm program payments; minus the area under the import, land, labor, AUMS and water supply curves; minus the miscellaneous cost of production. The overall value measure is the net present value of consumers' and producers' surplus. This is accumulated over the entire time frame of the model. The particular terms in the agricultural part of the objective function are:

< A negative entry for the crop production variables giving production costs for program and nonprogram crops where the cost is the sum of several miscellaneous cost items and farm profits

< A negative entry for the livestock production variables giving production costs including profits and miscellaneous cost

< A negative entry for the land supply curves for pasture, and cropland. The calculations can involve a constant elasticity, fixed price or fixed quantity supply curve

< A negative entry for the AUM private supply variables giving the area under the supply curve

< A negative entry for the AUM fixed price supply variables giving the price at which such grazing land can be rented

< A negative entry for the pumped water variables giving the area under the pumped water constant elasticity supply curve

< A negative entry for the fixed price water variables giving the price of fixed water

< A negative entry for the hired labor variables giving the area underneath the hired labor constant elasticity supply curve

< A negative entry for the family labor variables giving the price of family labor

< A negative entry for the input acquisition variables giving the input prices

- A positive entry under the domestic demands giving the area underneath the primary and secondary demand curves. The demand curves are constant elasticity curves. There also is a provision for the demand curve to be either fixed price, where the area is price times quantity, or fixed quantity in which case no area is entered. The demand curve integration also involves a truncation factor, where the demand curve is integrated from the larger of 1/10 of the quantity or the quantity that would cause 10 times the price. This is done since the constant elasticities demand curves go asymptotic to the axis and can lead to very large areas.

- A positive entry under the export demand variables giving the area under the curves for both primary and secondary commodities computed in a fashion analogous to the domestic demand

- A negative entry under the import supply curves giving the area under the curve for both primary and secondary commodities, again, with provisions for fixed price and fixed quantity curves

- A positive entry for the loan rate variables, reflecting revenue from placing crops under loan

- A positive entry for the deficiency payments variables, reflecting farmer revenues from government deficiency payments; this will be iterated over when the farm program is present

- A positive entry for the 50/92, unharvested acreage, artificial, and diverted acreage variables, reflecting payments.

3.2.4.2 Agricultural Land Balance

The agricultural land balance equations equate the pasture, and cropland utilized for agriculture with the land supplied. The equations also include the consideration of the land migrating in and out of agriculture to the forest sector. The land equations are defined by decade, region, and land type. The coefficients in this equation include:

- A plus and minus one for the land transferred to and from forestry variables depending on whether the land is being transferred in or out

- A positive land use by crops planted under the farm program variables. The coefficients here are one plus the set-aside rate adjusted for the participation rate
- A positive one under the nonprogram and nonparticipating production variables, reflecting land use
- A positive entry under the livestock production variable, indicating crop and pasture land use by livestock
- A negative entry under the land supply variable, indicating that land is supplied.

3.2.4.3 Maximum Land

The maximum amount of land that can be used is limited for each decade, region, and land type. The coefficients as for the equation are:

- A positive one for the land supply variable, reflecting land use.
- A positive right-hand side entry giving the maximum amount of the land used in the past twenty years as an upper bound on land use by region.

3.2.4.4 AUM Grazing Balance

The AUM grazing balance equation links usage of AUM grazing with the supply from public and private sources by region and decade. The coefficients in this equation include:

- A positive entry under the livestock production variables giving AUM grazing use by livestock; the coefficients reflect the AUM grazing requirements as specified in the livestock data
- A negative one under the private land grazing supply variables, reflecting AUM supply
- A negative one under the public land grazing supply variables, reflecting AUM supply.

3.2.4.5 Maximum Public AUM Availability

Public AUMS are limited to their maximum availability by region and decade. The coefficients in this equation include

< A positive entry under the public land AUM supply variables

< A positive entry on the right hand side giving endowment of AUMS by region.

3.2.4.6 Water Balance

Water supply and use is balanced by decade and region. Coefficients appearing in this equation are as follows:

< A positive entry for irrigated crop production possibilities for both participating and nonparticipating possibilities giving water use

< A positive entry for livestock production, reflecting water use

< A negative one under the fixed price water supply variables, reflecting water supply

< A negative one under the variable price (pumped) water supply, indicating water supply.

3.2.4.7 Maximum Fixed Price Water

The maximum amount of fixed price water is limited by region and decade. These equations contain:

< A positive one under the fixed price water supply variable

< A positive right hand side giving the quantity available.

3.2.4.8 Labor Balance

Labor use from livestock and crop production is balanced with labor from hired and family sources. The constraint is disaggregated by region and decade. The coefficients are as follows.

< A positive entry for the participating and nonparticipating crop production variables giving labor usage

< A positive entry for the livestock production variables giving labor usage

< A negative one for the family labor supply variable, indicating supply

< A negative one for the hired labor supply variable, indicating supply.

3.2.4.9 Family Labor Limit

The maximum amount of family labor available is constrained as that available in each decade and region. These equations contain:

< A plus one under the family labor supply variable

< A positive RHS value indicating the quantity of family labor available.

3.2.4.10 Hired Labor Limit

The maximum amount of hired labor that can be used in each decade and region is bounded here. These equations contain:

< A plus one under the hired labor supply variable

< A positive RHS value indicating the maximum quantity of hired labor available.

3.2.4.11 Input Acquisitions Balance

Input acquisition is balanced with input use by input and decade. The entries are

< A positive entry under the crop and livestock production variables, reflecting input use

< A negative one under the input acquisition variables, reflecting supply of inputs.

< A positive entry under the processing variables, reflecting input use

3.2.4.12 Primary Commodity Balance

A balance is struck between the primary commodities produced and the commodities consumed for each of the primary commodities in each decade. The entries in this equation are:

- A negative entry under the participating farm program variable, reflecting yield. The amount entered is that from the nonparticipating part of the variable (See Chang et al.) plus the amount produced that is not subject to deficiency payments. Thus, the entries are the portion of the commodity yield which is not eligible for deficiency payments. The amount eligible for deficiency payments is recorded in a farm program row.
- A negative entry for the nonparticipating production variables, reflecting yield
- Both positive and negative entries for the livestock production variables, reflecting the use of primary commodities as feedstuff as well as production (negative) of livestock commodities
- Both positive and negative entries under the processing variables, depending on whether the primary commodities are being used or supplied by the processing variables; generally, these are positive, indicating use of the primary commodity
- A positive one under the primary domestic demand variables, reflecting use of the primary commodity
- A positive one, indicating demand under the primary export variables
- A negative one under the primary import variables, indicating demand
- A positive one under the CCC loan purchase variables, indicating use.
- A negative one under the deficiency payment variables making participating production available to the market after the deficiency payment is paid

3.2.4.13 Secondary Commodity Balance

This balance is largely identical to the primary balance except that the farm program considerations are not entered. The entries are:

- A positive entry for the livestock production variables, indicating the use of the secondary products (such as the use of feed)

- Both positive and negative entries under the processing variables, indicating the usage and supply secondary of products

- A positive one for the domestic demand and export variables, indicating the use of the commodity in consumption

- A negative one for the import supply variables, reflecting supply.

- A positive one for the CCC Loan variables, reflecting the receipt of a CCC Loan on secondary commodities like butter

3.2.4.14 Farm Program Production Balance

Production under the farm program that is eligible for deficiency payments is balanced with that amount receiving deficiency payments by commodity and decade. The coefficients are:

- A negative entry under the participating crop production variables giving the maximum of the farm program yield and the actual yield times the participation fraction for the participating production variables indicating the amount of production eligible for farm program payments

- A positive one under the deficiency payment variables, indicating receipt of payments.

3.2.4.15 50/92 Balance

The amount of production foregone by participation in the 50/92 program is balanced with an variable which pays for the 50/92 program. This is controlled by decade and crop. The entries consist of:

- A negative entry under the participants production variables giving the farm program yield times 92% of the production times the participation fraction times the amount of acreage that falls under 50/92

- A positive one under the 50/92 payment variable.

3.2.4.16 Diverted Acres

This is similar in concept to the 50/92 row above where the foregone production on the acreage diverted is balanced with that receiving payments. This is controlled by decade and crop.

3.2.4.17 Artificial Production

The amount of production that is eligible for deficiency payments does not always equal actual production. Eligible production is balanced with the artificial payments. This recorded by decade and crop and is done as in the above 50/92 balance.

3.2.4.18 Unharvested Acres

Here again, the amount of yield foregone on unharvested acreage is balanced with payments for unharvested yield by decade and crop.

3.2.4.19 Crop Mix Balances

The crop mixes are controlled both by crop and region as well as in total in a region. The entries in these rows include:

< A positive one under the production variables, indicating the harvested acres of the crops produced

< Negative coefficients under the crop mix variable, indicating the amount of the crop that appears in each of the crop mixes and the sum of acres in the total mix rows

< A positive one under the Tolerance variables.

3.2.4.20 National Mix Balances

The regional distribution of production of certain commodities is controlled so it falls in the pattern exhibited by historical mixes of those commodities among regions by decade. The balances are present for the controlled commodities in each region.

< A positive entry under the crop production variables, reflecting the amount of the commodity being produced by the crop production variables in the region

< A positive entry for the livestock variables, reflecting the amount of the primary commodities produced by livestock production

< A negative entry under the national mix variables giving the production of each of the controlled commodity observed in each of the representative years by region.

4.0 FASOM OUTPUTS AND POLICY APPLICATIONS

This section describes the outputs of the FASOM model. It also discusses some of the policy questions the model can be used to address and shows how FASOM would be applied in these cases. Finally, it suggests some directions for future model revisions and modifications to improve FASOM and expand the scope of policy questions it can be used to address. A detailed listing of model outputs is contained in Appendix E.

4.1 MODEL SOLUTION INFORMATION

The FASOM solution is addressed here both in terms of the information it yields and its economic properties. The FASOM objective function involves the maximization of the present value of consumers' plus producers' surplus net of transport and capacity costs. It depicts (assumes), therefore, a multi-period simulation of economic activity in competitive sectors under perfect foresight of future price conditions. The sizes of timberland holdings are assumed to be small enough that owners do not individually affect prices but are knowledgeable of future forest product prices and land opportunity costs. Harvest decisions are made so that stands are harvested at the point where the (marginal present) value of wood and carbon growth (if priced) is no larger than the (present value of) marginal costs of maintaining the stand plus the marginal opportunity cost of holding the land in the current stand for an additional period (the present value of future rotations). In addition, the movement of land into forestry from agriculture will occur if the expected returns in forestry exceed the returns in agriculture over the remaining decades in the model plus the terminal values. The decision regarding transferring land to agriculture would involve the opposite considerations.

The solution to the nonlinear programming problem in FASOM provides the following information in eight areas:

- Consumers' and producers' welfare
- Agricultural production and prices
- Forest inventory amounts
- Harvest levels and prices
- Wood product output and prices
- Land and forest asset values

- Carbon sequestration amounts and "prices"
- Land transfers.

Appendix E lists a definition of items in current versions of the FASOM output.

4.1.1 Consumer and Producer Welfare

As previously stated, the FASOM objective function represents the net present value of consumer and producer surplus in the two sectors. Consumers' surplus is calculated in both sectors. Producers' surpluses is calculated regionally. Thus, the model produces information about the distribution of the present and future values of consumers' and producers' surplus over both space and time.

4.1.2 Agricultural Production and Prices

FASOM provides regional level information about the market-clearing production and price levels for all of the ASM commodities at the regional level by decade. Regional production levels for crops can be further broken down into average yield levels and acreage harvested. Price levels for agricultural products are endogenous in FASOM.

Tree planting programs have the potential to reduce input use by farmers. Annual management costs associated with tree plantations are considerably below agricultural production costs. Large enough reductions in input use by farmers may cause the prices of some inputs, such as hired labor and water to decrease. FASOM contains input supply curves for land and hired labor. Consequently, price (and cost) impacts on these inputs are an output of FASOM. The impacts of reductions in the use of other inputs can be measured, in aggregate, in terms of cost decreases to farmers, or as revenue decreases to input suppliers (on the other side of the balance sheet).

4.1.3 Forest Inventory Levels

For each 10 year period in the simulation period, FASOM reports regional inventory levels by owner, land use suitability, forest type/species, site class, management regime, and age -- in other words, by each of the dimensions that characterizes a representative inventory aggregate in the model. This level of detail can overwhelm an analyst, so inventory levels are usually aggregated over one or two descriptors, at most, at any one time, with forest type and owner being the most common and useful for regional-level analysis.

4.1.4 Harvest Levels and Prices

Harvest levels are provided by FASOM at the same level of detail as other inventory statistics. Regional and national price levels are output.

4.1.5 Wood Product Output and Prices

Wood product output levels, by period, will be provided for each of the three products (sawlogs, pulp, and fuelwood) at least by region and forest-type. Price levels for these products are endogenous.

4.1.6 Land and Forest Asset Values

Since FASOM simulates the competition between forest and agricultural activities for land, FASOM produces information about marginal land and forest asset values over time. Marginal land values for agricultural and forestland can be determined from shadow prices on the potential reforested land balance and on the agricultural land balance. Asset values for regional inventories can be calculated from this information using information about volumes per acre from the solution to the NLP.

4.1.7 Carbon Sequestration Amounts and Prices

FASOM will produce region- and national-level information about the total amount of carbon in storage in each period and the storage rate (i.e., change in storage) during each period. If carbon is "forced" into the model, then FASOM will generate an estimate of the shadow price associated with that requirement, provided that the constraint is binding.

4.1.8 Land Transfers

An important feature of FASOM is the intersectoral linkage between agriculture and forests. FASOM was designed so that transfers of land between sectors would occur endogenously within the model as a result of intertemporal economic forces. Thus, an important output of FASOM is the listing of land transfers that occur in each decade. These transfers are shown by region and sector (from - to) for each decade. Depending on the needs of the user, further breakdowns are possible showing the land class, crop or management intensity both from and to which land was transferred.

4.2 POLICY APPLICATIONS

The initial motivation behind FASOM was to develop a model to evaluate alternative policies to sequester carbon in an economic framework, one that could take into account not only the impacts of these policies on forest and agricultural sector markets, but also the reaction of consumers and producers in these markets to these policies. Subsequently, it became clear that FASOM could also be used to evaluate the carbon consequences of a wide range of forest and agricultural policies, not just those intended to promote carbon sequestration.

The scope of the policies and future scenarios that can be analyzed by FASOM taxes the imagination, since FASOM contains representations of both the agricultural and forest sectors and is the only model currently available to analyze land use substitution between the two sectors in a comprehensive and consistent economic framework. However, the potential of FASOM as a policy analysis tool can be illustrated by looking briefly at the way the model will be used, initially, to look at the following seven different policies and future scenarios.

4.2.1 Tree Planting Programs

A number of different programmatic features can be simulated using FASOM. The simplest approach involves using FASOM to develop carbon sequestration supply curves for different levels of carbon sequestration. These target levels can be specified on a decadal basis or over a longer period of time, for example the full 100 year simulation period, depending on policy dictates. By running FASOM repeatedly for alternative levels, one can obtain information to characterize marginal and total cost curves for both carbon and land. Such an analysis would show the welfare consequences and market impacts of different policy constraints. For example, policies that might be considered involve those that restrict harvesting of cost-shared tree plantations below a certain age class, or prevent harvesting entirely, although one should be cautious about forcing "old growth" forests for reasons stated earlier. Other types of constraints on the eligibility of land could be imposed to target specific types of land or to reflect the potential sluggishness of agricultural land owners in responding to these policies. Constraints could also be imposed to limit management alternatives to reflect potential conservatism in management.

The approach, outlined above, relies on the use of fixed RHS values for carbon and the subsequent parametric development of supply curves. An alternative, dual approach, involves "pricing" carbon in the objective function and then tracing out the marginal productivity (i.e., demand) and total benefit curves for carbon consistent with different levels of carbon sequestered at different prices. This approach can be implemented with and without a variety of constraints to reflect both policy and real world considerations, as in the initial approach.

4.2.2 Substitution of Tree Planting Subsidies for Farm Program Payments

The agricultural sector in FASOM can be set up to include (or exclude) the provisions of the current farm bill, or many other program alternatives. As such, it is possible to use FASOM to examine the effects of reducing loan rates and target prices, while increasing tree planting payments, like the current Conservation Reserve Program (CRP). The replacement type of analysis, indicated above, is an attempt to model policy trade-offs. However, the welfare consequences of switching subsidies could have dramatic implications for the distribution of welfare since farm programs keep agricultural prices low, while tree planting programs force these prices up. Therefore, an alternative analytic approach could involve using FASOM to estimate the level of sequestered carbon for which the reduction in deficiency payments (and replacement with carbon subsidies) will hold total welfare constant (at the baseline level).

4.2.3 Adoption of Advanced Agricultural Technology

Historically, the amount of land in agricultural production and the share of agricultural output in total GNP has been steadily dropping since the late 1900s. This trend has been taking place in spite of sustained population and income growth in the U.S., as well as recent surges in U.S. agricultural exports. This phenomenon is due largely to a combination of steady increases in agricultural productivity and the relatively price-inelastic nature of the demand for most agricultural commodities.

The long term effects of sustained agricultural productivity on U.S. agricultural policy is a topic that has important ramifications for programs to sequester carbon. High agricultural productivity reduces the number of acres required to produce a given amount of food, lowers the opportunity cost of "excess" agricultural land (i.e., those acres that are subsidized), and creates political incentives to increase agricultural subsidies, while at the same time it provides more potential land to be afforested. Thus, an important set of future scenarios to be considered by FASOM are those which include higher (and lower) rates of technological progress than have been observed historically. This is accomplished easily in FASOM by changing the FASOM data for expected gains in productivity.

4.2.4 Significant Changes in Net Export Demands for Key Crops

The history of American agriculture has shown a tendency for exports to fluctuate over both long and short cycles. For example, wheat exports in the mid-1970s reached all-time highs, after decades of relatively modest changes. Similarly, exports of corn and soybeans surged in the early 1980s, making the U.S. a world leader in the export of both products. The fluctuating character of export demands in the U.S. has provided one of many rationales for agricultural subsidies. At the same time, leadership in world export markets, such as the U.S. has enjoyed periodically in soybean markets, has provided an important stimulus to agricultural production. Given current political instability in some major food demand and supply regions, the potential for large increases in net export demands for some U.S. crops could be integrated into future scenarios developed for FASOM. Such increases have the effect of counteracting the impacts of increased productivity on tree planting programs as discussed in the previous section, although increased productivity is, at the same time, a key factor in lowering U.S. production prices closer to world levels. Increases in net export demands are easy to simulate in FASOM by shifting the export demand functions for those crops in which the U.S. might expect increases, such as corn and, possibly, wheat, and other major commodities where the comparative advantage between the U.S. and other nations could be narrowed.

4.2.5 Reforestation and Forest Management Programs

There have been several efforts to evaluate either the timber supply and/or carbon sequestration potential of various types of proposed reforestation programs, such as the Stewardship Incentive Program (SIP) and America the Beautiful (ATB). Studies by Dutrow et al. (1981) and the USDA Forest Service (1990) evaluated the timber supply potential of investment opportunities in the U.S., as a whole, while a subsequent study by Alig et al. (1992) evaluated forest investment opportunities in the South. A more recent study was undertaken by Moulton and Richards (1990) that looked at the carbon sequestration consequences of both afforestation and reforestation programs. Dutrow et al. (1981), USDA Forest Service (1990) and Alig et al. (1992) all estimated the potential amount of available acreage and the rate of return on investments in forest management, including both regeneration of new stands and improvement of existing stands. These studies both identified a range of potentially profitable investments in forest management, but did not model the effect of programmatic subsidy levels on investment enrollment. The study by Moulton and Richards, while it did provide cost-based supply curves for both timber and carbon on reforested land, did not take into account the effect of programmatic subsidy levels on acreage enrollment (i.e., used a social cost stance). Thus, their study may not provide an accurate indication of the potential acreage enrollment patterns that can be expected from programs like SIP or ATB.

In FASOM, all investments in land compete with each other at the margin in the asset market for land. Programs, like SIP and ATB, can be simulated in FASOM by reducing management costs to reflect program payments; by constraining program participation by total program costs or some State distribution of costs; and by introducing into FASOM changes in yields and costs to reflect the technology associated with eligible management alternatives.

4.2.6 Changing Harvest Levels on National Forest Land

Public policy on National Forest and other public timberland seems to be moving in the direction of increased set-aside of timberland for nontimber purposes, with either restricted timber harvests or no harvesting on some timberlands. This policy trend, if it continues, will result in smaller and smaller harvests of timber from public lands. This will allow carbon stored in existing trees to accumulate further, although at a slower rate as trees in the public inventory grow older. At the same time, potential land on which to plant new trees that can sequester carbon at a more rapid rate will decline. The net impact of these two forces on total carbon sequestration is made uncertain by a variety of factors, not the least of which involves knowing the rate at which carbon in wood products oxidizes after a tree is harvested. Thus, a continuation of current trends on public lands raises important policy questions that can not be answered easily without a model like FASOM.

While FASOM currently does not contain a detailed representation of the forest inventory on public lands, it includes harvesting from this land. Reductions in harvests from public lands can easily be simulated and it is possible to examine the impact of these reductions on harvesting and management investment decisions in the private sector and on the change in total carbon sequestration. Reductions in harvests from public lands can be treated as a policy in and of itself, or it can be included in a future scenario which is used to assess other policies.

4.2.7 Increases in Paper Recycling and Wood Processing Technology

There is growing interest in the impact of increased use of wastepaper as raw material for paper and various types of fiber board production. Producers in Japan and many other developed countries use almost twice as much wastepaper as raw material for the production of paper and board products as U.S. producers. Interest in this phenomenon led to an analysis of the impacts of increasing the use of wastepaper to levels observed elsewhere in the 1989 RPA (USDA Forest Service, 1990). The results of this analysis showed decreases in pulpwood use and increases in forest inventories. Haynes et al. (1994a) estimated the impact of these increases in inventory volumes on carbon sequestration, using the TAMM/ATLAS/area change modeling system.

While productivity in the forest products industry has not increased as rapidly as in the agricultural sector, a steady downward trend in log sizes has been accompanied by an increase in the amount of lumber than can be recovered from a given volume. Technological increases in various wood products markets have also substantially reduced real harvest costs; led to the adoption and rapid spread of various fibre board products that have replaced plywood; and have also caused reductions in the amount of material needed to make a number of primary and secondary wood products. Meanwhile, lower cost substitutes continue to replace wood fibre materials in a number of uses.

Because the stumpage and product demand relationships in FASOM are derived directly from TAMM, modeling both increased use of waste paper and technological change can be simulated by shifting the relevant product demand curves inside FASOM using information obtained from previous TAMM runs. The important difference between the results that are obtained from FASOM and those that have been obtained from TAMM, in the past, for these cases is that the foreseeable consequences of technological change on stumpage and product prices will influence the behavior of timberland owners in current periods.

4.3 FUTURE DIRECTIONS FOR FASOM

As previously stated, one of the principles guiding the development of FASOM involves building the modeling system in stages. In that regard, the first order of business has been to develop a working, validated version of the modeling system that incorporates the important features of the modeling system required by EPA's needs (joint markets and conversion activities, future price expectations, basic timber inventory, management investment, carbon sequestration accounting), and then expanding the system to meet other important needs of the agency.

It is somewhat difficult to foresee all of the modifications that might be needed. However, based on current work, there are several obvious future directions in which the model could be profitably extended. These include the following:

- Developing a better representation for the inventory on public timberland
- Enhancing carbon accounting in the agricultural sector to capture the effects of changes in management on carbon sequestration
- Adding biomass feedstocks and, possibly, conversion technologies to evaluate the costs and benefits of biomass plantations for offsetting "conventional fossil fuel emissions"
- Adding features to reflect the stickiness of forestry actions by certain ownership classes
- Adding features to estimate emissions of greenhouse gases from both sectors and calculate net carbon sequestration
- Including provisions for climate feedbacks on crops and forests, so that we could look at the interaction between the effects of climate change and efforts to mitigate them by reducing emissions

- Adding more forward market detail to better track the fate of carbon in wood products based on the behavior of these markets.

Each of these items is discussed in more detail in the ensuing text.

4.3.1 Public Inventory Modeling

As previously stated, the information regarding inventories of timber on public land is either extremely limited or very difficult to use for large scale studies and in some cases not of the same quality across regions of the country. Organizing this data, developing assumptions to fill in data gaps, etc., is a substantial, time-consuming effort. Consequently, a decision was made not to model this inventory in this version of FASOM. From a policy perspective, it seems less and less likely that public lands will play a large role in carbon sequestration. However, the impacts of reducing harvests on these lands and preserving old growth on carbon sequestration in other "parts" of the forested land in the U.S is an issue that warrants consideration in future work. As improved data on public timber resources accumulates, the inventory detail in FASOM can be improved accordingly. The first stage of related future work could be to test the integration of existing information about the inventory in Washington and Oregon into the model. However, as stated earlier, sufficient information for this region may not be available until the 1998 RPA Assessment. This can be followed by incorporating improved inventory data for California and the Rocky Mountain region as they accumulate. For the East, assembly and processsing of National Forest data coordinated by Richard Birdsey at the NE Station of the USDA Forest Service could be reviewed as a starting point to evaluate whether that data could be used in some form into FASOM.

4.3.2 Enhanced Carbon Accounting for the Agricultural Sector

In the current version of the model, only a base level of agricultural soil carbon is modeled. Effects of changes in agricultural practices are ignored. It would be possible to modify FASOM to answer these questions by introducing specific tillage variables and associated carbon capture coefficients into the agricultural sector in FASOM. The parent ASM model already has a version with tillage alternatives. However, information on the effects of tillage practices on carbon is incomplete. The major research issues associated with including carbon accounting in the agricultural sector are: a) whether it is worth expanding model size to include all of the appropriate cropping variables; and b) developing a consistent set of net sequestration coefficients for these variables in the model. A related issue is whether the model ought to be extended, still further, to include greenhouse gas emissions coefficients so that one could explore the effects of alternative policies on net emissions from the sector in a simultaneous framework.

4.3.3 Adding Biomass Activities

The current version of FASOM is equipped to look at policies to store carbon in trees. It is not equipped to look at policies to encourage the production of biomass-based energy that can displace conventional fossil fuel emissions. FASOM can be modified to assess these policies. The existing agricultural sector model in FASOM already has most of the important agricultural commodities with which feedstock "crops" must compete on the supply side. Biomass production and conversion could be added in three steps. First, feedstocks, either annual or short-rotation trees, would be included using available budget information. Second, sets of fuel and perhaps even energy production activities (covering all stages of production and marketing) would be added in each region, using one or more competing processes.[20] Finally, the model would be updated to track the carbon flow from these biomass products and the displacement of carbon in conventional fossil fuels.

By adding these activities to the model, conventional forest and agricultural activities would be forced to compete with feedstocks for land. In this framework, one can use FASOM to determine the cost-effectiveness of the alternatives for sequestering carbon and displacing emissions in a comprehensive policy. At the same time, one can evaluate the impacts of both approaches on markets and the distribution of consumer and producer welfare. The same modifications would allow FASOM to be used to develop supply curves, parametrically, for either feedstocks or biomass energy to be employed in more comprehensive energy models.

4.3.4 "Stickiness" in Timberland Management Investment Decisions

In the current model form, timberland management investment decisions depend exclusively on the prospective present net welfare impacts of the activities, where the intertemporal nature of these impacts is known with certainty. Investment decisions adjust "instantaneously" to any changes in externally imposed modeling conditions such as interest rate, intertemporal demand shifts, costs, and so forth or to conditions created by hypothetical policies such as the afforestation of marginal agricultural lands to sequester atmospheric carbon. It is commonly suggested, however, that such rapid adjustment does not accurately characterize actual investment behavior in the sense that investment decisions are "sticky" in nature, slow to change and exhibit some inertia.

Stickiness in investment decisions can arise for several reasons (Alig et al., 1990a):

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[20] An alternative would be to introduce, directly into FASOM, feedstock demand functions.

1. Failures in the assumption of perfect capital markets, including capital budgets or restrictions on borrowing, so that not all investments that promise to yield a positive present net welfare impact can be undertaken, and divergence in the lending and borrowing rates realized by investors.

2. Lumpiness or discreetness in investments that impose some minimum size or extent of investment.

3. Imperfections in investors' knowledge of future markets, including price impacts of future supplies restricted or augmented by investment decisions (the "price feedback" of investments), ignorance of future demand shifts, etc.

4. Uncertainty of future public programs related to timber supply or timber demand.

5. Forest landowners derive utility both from the goods that can be consumed using income derived from timber harvest **and** directly from the standing stock of timber itself or the wildlife and other nontimber forest outputs and services that depend on the stock and its characteristics (aesthetic and amenity values).

FASOM might be modified to simulate the effects of the first four of these considerations by: (i) introducing bounds or limits on the areas replanted in future time periods, or the areas replanted to the higher management intensity classes; (ii) imposition of explicit investment budgets; (iii) raising minimum harvest ages above the implicit optimal levels found in unconstrained runs (forcing retention of stands beyond economically optimal periods); or (iv) any of an array of restrictions decoupling the planting investment decision from perfect information on future prices, e.g., by requiring the replanting of some preset portion of the area harvested in each period to the lowest management intensity class or a portion based on some function of past prices.

The fifth area involves consideration of the utility function(s) of timber owners. Binkley (1987) and Kuuluvainen and Salo (1991) summarize recent research on the theoretical development and econometric testing of so-called "household production" models of forest landowner behavior in which owner utility depends on both harvest income and direct amenity outputs derived from the forest. Since little is known about the form of owner utility functions, implementation of a modification of this sort in FASOM would involve some essentially arbitrary assumption about the form and sensitivity of utility to aspects of the timber stock. An example of such an approach in the context of intertemporal harvest decisions is given by Max and Lehman (1988).

4.3.5 Estimation of Greenhouse Gas Emissions

The model, as currently structured, does not provide information about the production of greenhouse gases from forest and agricultural activities. In fact, the ASM model has been used for this purpose in at least one published study (Adams et al., 1992). Adding emissions coefficients for the various greenhouse gases in the two sectors is a difficult task from the standpoint of finding data to support and develop a comprehensive and consistent set of emissions coefficients for appropriate variables in the agricultural sector. However, by adding this capability to the model, it would be possible to maintain an account for net emissions (i.e., emissions less sequestration and displacement) either on a gas by gas basis or in terms of the combined Global Warming Potential (GWP) of the various gases produced and carbon stored in the two sectors.

4.3.6 Inclusion of Climate and CO_2 Fertilization Feedbacks

Both ASM and TAMM have been used to model the effects of changes in yields due to air pollution and other factors on the agricultural and forest sectors, respectively. Since FASOM retains the important structural elements of both models to do this, it follows that FASOM can also be used to look at the interaction between the effects of climate change and mitigation of these effects through carbon sequestration policies. The agricultural sector in FASOM is already well-developed to look, simultaneously, at the effects of climate-induced changes in yields and reductions in water availability on both dryland and irrigated agriculture and the effects of higher CO_2 on crop yields and water use efficiency. However, both climate-induced changes in yields, as well as those due directly to CO_2 fertilization, in the forest sector are more difficult to model accurately with the current version of FASOM due to the potential for forest type transitions to occur as climate changes. A first-order analysis of the effects of climate change could be undertaken by changing the growth and yield tables in each region to reflect the best available information on productivity changes due to the effects of climate and CO_2 fertilization. However, this approach does not accurately capture changes in species composition and acreage in the inventory due to transition.[21] To simulate these changes will require expanding the species-level variety in the growth and yield tables and cost budgets in the model and then exogenously introducing these transition changes over time into the model, based on available evidence about the effects of climate changes on forest growth and transition.

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[21] It is also debatable if information about simulated transitions within unmanaged forest ecosystems from one forest type to another is relevant to managed forests where, in some very prominent cases, the "natural" climax species is removed or thinned from stands to allow an economically more attractive species to dominate.

4.3.7 Adding Forward Markets

The TAMM model, on which certain features of the forest sector in FASOM are based, is a two-level model, which includes both a set of regional stumpage markets and a set of regional primary product markets for the most important primary products. In FASOM, this structure is collapsed into a single market for stumpage products (sawlogs, pulpwood, and fuelwood). This was done as a practical consideration, since adding more market levels increases the complexity and size of the model, although if the translation from two into a single set of markets is done correctly all of the information contained in the original demand curves ought to be preserved. What is lost in this process is the ability to trace the fate of carbon in products in such a way that the distribution of products is based on economic behavior. In the current version of FASOM, the distribution of forward products will be assumed to be fixed at some representative mix, and carbon fate will be tracked exogenously for this mix. It would be preferable to have the model, itself, solve for this mix of products in primary markets.

This modification can be accomplished by importing the two levels of demand curves from TAMM directly into FASOM and then adding carbon decay coefficients that are specific to each product. Carbon fate in subsequent phases of the product life cycle would remain fixed. This is a large task in terms of the amount of data that would have to be taken from TAMM and then modified to fit the dynamic structure of FASOM.

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APPENDIX A

SCOPE OF THE ASM VERSION IN FASOM

This appendix documents the basic assumptions and elements regarding the agricultural sector model (ASM) of the United States that is currently residing in FASOM. Various versions of the ASM have been and are being used to investigate the economic impacts of technological change, trade policy, commodity programs, introducing new products, environmental policy, and global warming on the U.S. agricultural sector (Baumes, 1978; Burton and Martin, 1987; Chattin, 1982; Tyner et al., 1979; Hamilton, 1985; Adams, Hamilton, and McCarl, 1986; Hickenbotham, 1987; House, 1987; Tanyeri-Abur, 1990; Coble et al., 1992; Chang et al., 1992; Chang, Eddleman, and McCarl, 1991; Adams et al., 1993).

Conceptually, the ASM is a price-endogenous mathematical programming framework following the spatial equilibrium concept developed by Samuelson (1952), Takayama and Judge (1971) as reviewed by McCarl and Spreen (1980) and Norton and Schiefer (1980). The model was originally designed to simulate competitive equilibrium solutions under a given set of demand and supply conditions. The objective function is the summation of all areas beneath product demand curves minus the summation of all areas under import and factor supply curves; i.e., the area between the demand and supply curves to the left of their intersection. This area is also referred to as producers' and consumers' surplus in the economic literature. This objective function represents a social welfare function which measures the benefits of producers' and consumers' from producing and consuming the agricultural commodities. The production and consumption sectors are made up of a large number of individuals operating under the competitive market conditions. When producers' plus consumers' surplus is maximized, the model solution represents an intersection of supply and demand curves and, thus, simulates a perfectly competitive market equilibrium. Therefore, prices for all factors of production and outputs are endogenously determined by the supply and demand relationships of all the commodities in the model.

The agricultural sector model component is designed to simulate the effects of various changes in agricultural resource use or resources availability, in turn determining the implications for prices, quantities produced, consumers' and producers' welfare, exports, imports and food processing. In doing this the model considers production, processing, domestic consumption, imports, exports and input procurement. The model distinguishes between primary and secondary commodities with primary commodities being those directly produced by the farms and secondary commodities being those involving processing. For production purposes the U.S. is disaggregated into 63 geographical subregions. Each subregion possesses different endowments of land, labor and water as well as crop yields. Therefore, the disaggregate information is also an important feature in this model. The supply sector of the model works from these regional input markets and a set of regional budgets for a number of primary crops and livestock and a set of national processing budgets which uses these inputs. There are also import supply functions from the rest of the world for a number of commodities. The demand sector of the model is constituted by the intermediate use of all the primary and secondary commodities, domestic consumption use and exports. Details on the items mentioned above follow.

A1.0 PRIMARY COMMODITIES

There are 33 primary commodities in the model. These are listed in Table A-1. The primary commodities are chosen so as to depict the majority of total agricultural production, land use and economic value. They can be grouped into crops and livestock.

Both supply and demand information (i.e., prices, quantities, slopes and/or elasticities) are required in the model. The total supply consists of domestic production from all agricultural regions and imports. Total demand is made up of domestic and foreign (or export) components. Domestic demand includes food consumption, CCC stock, livestock feed and processing. Transportation costs to the market are included in the supply budget. Livestock feed and processing demands are endogenously determined. The prices and quantity data came from Agricultural Statistics, Agricultural Prices Annual Summary, and Livestock and Meat Statistics Supplement. Elasticity, slope, and other information came from Baumes, Burton, Tanyeri-Abur and Bob House in the USDA.

A2.0 SECONDARY COMMODITIES

The model incorporates processing of the primary commodities. The production of primary commodities are regionally specified, but the processing of secondary commodities is done in the overall U.S. aggregate sector. Table A-2 lists the 37 secondary commodities that are processed in the model. These commodities are chosen based on their linkages to agriculture. Some primary commodities are inputs to the processing activities yielding these secondary commodities and certain secondary products (feeds and by-products) are in turn inputs to agriculture. The primary data sources were Agricultural Statistics, Agricultural Prices Annual Summary, Livestock and Meat Situation, and Livestock Slaughter Annual Summary.

A3.0 NATIONAL INPUTS

The model contains 24 national inputs. They are listed in Table A-3. For the most part these are specified in dollar terms; for example, ten dollars worth of nitrogen, twenty dollars worth of repairing cost. In doing so, the input use is converted into a homogeneous commodity. These inputs are usually assumed infinitely available at fixed prices and the prices are updated annually according to the paid-by-farmers index in Agricultural Statistics.

A4.0 REGIONAL DISAGGREGATION

The model operates with the 11 region FASOM regional disaggregation. The data from the full 63 region version of ASM are aggregated to this basis.

Table A-1. Primary Commodities

	Crop Commodities	Units		Livestock Commodities	Units
1	Cotton	Bales	14	Milk	Cwt
2	Corn	Bushel	15	Cull Dairy Cows	Head
3	Soybeans	Bushel	16	Cull Dairy Calves	Head
4	Wheat	Bushel	17	Cull Beef Cows	Cwt, LW
5	Sorghum	Bushel	18	Calves	Cwt, LW
6	Rice	Cwt	19	Yearlings	Cwt, LW
7	Barley	Bushel	20	Nonfed Beef	Cwt, LW
8	Oats	Bushel	21	Fed Beef	Cwt, LW
9	Silage	Ton	22	Veal Calves	Cwt, LW
10	Hay	Ton	23	Cull Sows	Cwt, LW
11	Sugar Cane	1000 lbs	24	Hogs	Cwt, LW
12	Sugar Beets	1000 lbs	25	Feeder Pigs	Cwt, LW
13	Potatoes	Cwt	26	Poultry	GCAU
			27	Cull Ewes	Cwt, LW
			28	Wool	Cwt
			29	Feeder Lambs	Cwt, LW
			30	Slaughter Lambs	Cwt, LW
			31	Unshorn Lambs	Cwt, LW
			32	Wool Subsidy	$
			33	Other Livestock	GCAU

Note: LW indicates live weight
GCAU is grain consuming animal unit.

Table A-2. Secondary Commodities

	Crop Commodities	Units		Livestock Commodities	Units
1	Soybean Meal	Cwt	25	Fluid Milk	Cwt
2	Soybean Oil	1000 lbs	26	Skim Milk	lb
3	Raw Sugar	1000 lbs	27	Nonfat Dry Milk	lb
4	Refined Sugar	1000 lbs	28	Cream	lb
5	Corn Starch	1000 lbs	29	Butter	lb
6	Corn Gluten Feed	1000 lbs	30	Ice Cream	lb
7	Corn Oil	1000 lbs	31	American Cheese	lb
8	Ethanol	1000 lbs	32	Other Cheese	lb
9	HFCS	1000 lbs	33	Cottage Cheese	lb
10	Corn Syrup	1000 lbs	34	Fed Beef	Cwt,CW
11	Dextrose	1000 lbs	35	Nonfed Beef	Cwt,CW
12	Confectioneries	1000 lbs	36	Veal	Cwt,CW
13	Beverages	1000 lbs	37	Pork	Cwt,CW
14	Baked Goods	1000 lbs			
15	Canned Goods	1000 lbs			
16	Dried Potatoes	Cwt			
17	Chipped Potatoes	Cwt			
18	Frozen Potatoes	Cwt			
19	Feed Grains	1000 lbs			
20	Dairy Protein Feed	1000 lbs			
21	High Protein Swine Fd	1000 lbs			
22	Low Protein Swine Fd	1000 lbs			
23	Low Protein Cattle Fd	1000 lbs			

24	High Protein Cattle Fd	1000 lbs

Note: Cw mean carcass weight.

Table A-3. National Inputs

Lists of Inputs		Units
1.	Nitrogen	$
2.	Potassium	$
3.	Phosphorous	$
4.	Lime	$
5.	Other Chemicals	$
6.	Custom Operation	$
7.	Seed Costs	$
8.	Fuel and Energy Costs	$
9.	Interest on Operating Capital	$
10.	Irrigation Energy Cost	$
11.	Repair Costs	$
12.	Vet and Medical Costs	$
13.	Marketing/Storage Costs	$
14.	Insurance (Except Crop)	$
15.	Machinery	$
16.	Management	$
17.	Land Taxes	$
18.	General Overhead Costs	$
19.	Noncash Variable Costs	$
20.	Crop Insurance	$
21.	Land Rent	$

22.	Set-Aside (Conservation Cost)	$
23.	Processing Labor	$
24.	Other Variable Costs	$

A5.0 REGIONAL INPUTS

There are four inputs that are available at the regional level; water, AUM grazing, land, and farm labor. Production of crops and livestock compete for these scarce resources in each region. Therefore, the price and quantities of these inputs are determined on a regional basis
Two major types of land are specified. The first one (type 1) is land suitable for crop production. The second land type (type 2) is suitable for pasture or grazing. The availability on these two types of land was derived from Agricultural Statistics. The regional prices of these land were derived from the information in Farm Real Estate Market Developments. Cash rental prices of land were used to reflect annual opportunity costs to the owners.

The grazing land supply is divided into public and private grazing. Public grazing is available at a constant price while private grazing can be obtained by a upward- sloping supply schedule. Information on public grazing comes from the Grazing Statistical Summary by USDA Forest Service and Public Land Statistics by the Bureau of Land Management in the U.S. Department of the Interior. Private grazing information comes from the estimates in An Analysis of the Range Forage Situation in the United States: 1989-2040 by L.A. Joyce. Information on grazing fees originates from Estimating Forage Values for Grazing National Forest Lands by W.F. Hahn et al. and the Bureau of Land Management.

The labor input also include two components: family labor and hired labor. The model requires specification of a maximal amount of family labor available, and a reservation wage for family labor. The additional labor to be hired is based on an inducement wage rate which is higher than the reservation wage. The regional information about the quantities and wages was obtained from Farm Labor.

The water input is also divided into fixed (or surface) and variable available (or pumped ground) water and is supplied. The fixed water is available for a constant price but the amount of variable water is provided according to a supply schedule where increasing amounts of water are available for higher prices. The information on water came from USDA and NASS sources who used the Farm and Ranch Irrigation Survey and other government sources in its formation.

A6.0 REGIONAL PRODUCTION ACTIVITIES

Currently more than 200 production possibilities (budgets) are specified to represent agricultural production. These include major field crop production, livestock production, tree production and some miscellaneous transfer activities. Some field crop activities are also divided into irrigated and nonirrigated according to the irrigation facilities available in each region.

In some cases, the production possibilities produce more than one commodity. All commodities are produced by more than one production possibility. Most field crops (except rice) are produced by either irrigated or nonirrigated production practices. Livestock production is somewhat more complicated. Table A-4 lists the main types of production activities and details the relationship between the production activities and primary commodities.

For each activity, information on yields, and uses of national and regional inputs or other commodities is required. The basic source of these information is the 1982 USDA FEDS budget. The irrigated/nonirrigated budget breakdown arose from the USDA water group who developed budgets based on the FEDS survey sources, the survey of irrigated acreage, extension budgets and SCS budget sets.[22] The yields in all the crop budgets were updated annually according to the Agricultural Statistics. The Livestock budgets came straight from the FEDS system 1982.[23] Some of their yields could also be updated by the information available in the Agricultural Statistics.

A7.0 PROCESSING ACTIVITIES

The secondary commodities are produced by a number of processing activities. They are soybean crushing, corn wet-milling, processing of potatoes, sweeteners, and timber, combining feed ingredients into various livestock and poultry feed, and the conversion of livestock and milk into consumable meat and dairy products. Processing cost of each commodity is calculated as the difference between its price and the costs of the primary commodity inputs. A list of the processing activities is given in Table A-5.

Soybean crushing involves conversion of soybean meal and oil. Two soybean crushing activities are included so that the model can select the more profitable one. The meat processing includes conversion from culled animals to slaughter and from slaughter to meat. The dairy processing involves conversion of raw milk to five different dairy products. The feed alternatives involve multiple processing activities so that the model can select the least cost combination of feed ingredients.

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[22] Thanks to Bob House, Marcel Aillery, Glen Schaible and Terry Hickenbotham in the USDA/ERS Policy and Soil and Water Groups for making these data available.

[23] Thanks to Bob House and Terry Hickenbotham for making these data available.

Table A-4. Production Activities and Primary Commodities

(I). Crop Production

Production Activities	Primary Commodities
Cotton Cotton Irrigated	Cotton
Corn Corn Irrigated	Corn
Soybeans Soybeans Irrigated	Soybeans
Wheat Wheat Irrigated	Wheat
Sorghum Sorghum Irrigated	Sorghum
Rice Irrigated	Rice
Barley Barley Irrigated	Barley
Oats Oats Irrigated	Oats
Silage Silage Irrigated	Silage
Hay Hay Irrigated	Hay
Sugar Cane Sugar Can Irrigated	Sugar Cane
Sugar Beets Sugar Beets Irrigated	Sugar Beets
Potatoes Potatoes Irrigated	Potatoes

Table A-4 (continued). Production Activities and Primary Commodities

(II). Livestock Production

Production Activities	Primary Commodities
Beef Cow	Cull Beef Cows, Beef Feeder Yearlings, Live Calves
Beef Feed	Slaughtered Fed Beef Cows
Cow Calf	Cull Beef Cows, Live Calves, Beef Feeder Yearlings
Dairy	Milk, Cull Dairy Cows, Live Calves
Farrow Finishing	Hogs for Slaughter, Cull Sows
Feeder Pig	Feeder Pigs, Cull Sows
Feedlot	Slaughtered Fed Beef Cows
Hog Farrow	Hogs for Slaughter, Cull Sows
Pig Finishing	Hogs for Slaughter
Other Livestock	Other Livestock (Primary Horses)
Poultry	Poultry
Sheep	Slaughtered Lambs, Feeder Lambs, Culled Ewes, Wool, Wool Incentive Payments, Unshorn Lamb Payments
Stocker	Live (Beef Feeder) Calves, Slaughtered Nonfed Beef

Table A-5. Processing Activities

Processing Activities	Number of Activities
Soybean Crushing:	
Soybean to soybean meal and oil	2
Livestock to Meat and Dairy Products:	
Culled Beef Cow to Nonfed Slaughter	1
Culled Dairy Cow to Nonfed Slaughter	1
Beef Feeder Yearling to Nonfed Slaughter	1
Nonfed Slaughter to Nonfed Beef	1
Live Calf to Calf Slaughter	1
Culled Dairy Calf to Calf Slaughter	1
Calf Slaughter to Veal	1
Fed Slaughter to Fed Beef	1
Hog Slaughter to Pork	1
Sow Slaughter to Pork	1
Raw Milk to Skim Milk and Cream	1
Raw Milk to Fluid Milk and Cream	1
Raw Milk to Butter and Nonfat Dry Milk	1
Cream and Skim Milk to American Cheese	1
Cream and Skim Milk to Other Cheese	1
Cream and Skim Milk to Ice Cream	1
Cream and Nonfat Dry Milk to Ice Cream	1
Cream and Skim Milk to Cottage Cheese	1
Livestock Feed Mixing:	
Feed Grain	6
Dairy Protein Feed	6
High Protein Swine Feed	1
Low Protein Swine Feed	2
High Protein Cattle Feed	1
Low Protein Cattle Feed	4
Potato Processing:	
Potatoes to Frozen Potatoes	1
Potatoes to Potato Chips	1

Potatoes to Dehydrated Potatoes	1

Table A-5 (continued). Processing Activities

Processing Activities	Number of Activities
Corn Wetmilling:	
Corn to Corn-Oil, Gluten Feed, and Starch	1
Gluten Feed to Soybean Meal	1
Starch to HFCS	1
Starch to Corn Syrup	1
Starch to Dextrose	1
Starch to Ethanol	1
Sweetener Processing:	
HFCS and Refined Sugar to Beverages	1
HFCS and Refined Sugar to Confectioners	1
HFCS and Refined Sugar to Canned Good	1
HFCS and Refined Sugar to Baked Good	1
Sugar Cane to Cane-Refinering	1
Cane-Refinering to Refined Sugar	1
Sugar Beets to Refined Sugar	1

A8.0 CROP MIXES

The sector model disaggregated into 63 regions. Within each region, individual crop production was often represented by one budget. Such representation cannot capture the full factor-product substitution possibilities in each of those areas. In cases, this can lead to quite misleading results. This is avoided by requiring the crops in a region to fall within the mix of crops observed in the Agricultural Statistics historical cropping records. The model is constrained so that for each area the crop mix falls within one of those observed in the past 20 years.

APPENDIX B

DATA USED IN MODELING THE FORESTRY SECTOR IN FASOM: TIMBER GROWTH AND YIELD, TIMBER MANAGEMENT COSTS, AND LAND USE CHANGES

The objective of this appendix is to provide more detailed information than is in the text about the following topics:

- General makeup of the forest sector portion of the model and important definitions
- Data formats and data sources for the forest sector portion of the model
- Treatment of land uses changes involving the forest sector
- A glossary of forestry terms.

B1.0 GENERAL FORMAT AND DEFINITIONS

The first-generation FASOM model was developed using the strata presented in Table B-1 to describe the private timberland base.

Table B-1. State Used in FASOM: Regional, Land Class, Ownership Group, Species, Site, Management Intensity, and Age

Region	CLS	Owner	Species	Site	MIC	Cohort
NE	FORONLY	FI	SOFSOF	HIGH	LO-LO	0TO9
LS	CROPFOR	OP	HARHAR	MED	LO	10TO19
CB	PASTFOR		HARSOF	LOW	ME	20TO29
SE	FORCROP		SOFHAR		HI	30TO39
SC	FORPAST					40TO49
RM						50TO59
PSW						60TO69
PNWW						70TO79
PNWE						80TO89
						90PLUS

B1.1 LAND CLASS (CLS)

FASOM includes five land classes in its structure. These include:

FORONLY	Includes timberland acres which are not converted to agricultural uses
FORCROP	Includes acres which begin in timberland and which can be converted to crop
FORPAST	Includes acres which begin in timberland and which can be converted to pasture
CROPFOR	Includes acres which begin in crop and which can be converted to timberland
PASTFOR	Includes acres which begin in pasture and which can be converted to timberland.

B1.2 OWNERS

FASOM includes two different private, forest owner groups. These owner groups include:

FI	Forest industry
OP	Other private.

The traditional definitions are used, where industrial owners possess processing capacity, and other private owners do not.[24]

B1.3 SPECIES

FASOM employs four different species types, as follows:

SOFSOF	Softwood forest type in current and subsequent model periods
HARHAR	Hardwood forest type in current and subsequent model periods
HARSOF	Hardwood forest type that is naturally regenerated or replanted to softwood type
SOFHAR	Softwood forest type that is regenerated or replanted to hardwood type.

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[24] Unlike Powell et al. (1993), the Other Private inventory in FASOM does not include Native American lands. Harvests on these lands are included with the Other Public exogenous harvest group.

B1.4 SITE

FASOM includes three different site classes. Site classes are a measure of forest productivity. These site classes include:

HIGH	High site productivity group (as defined in ATLAS)
MEDIUM	Medium site productivity group
LOW	Low site productivity group.

The site groups were defined based on ATLAS inputs from the 1993 RPA Update (Haynes et al., 1994b). Productivity ranges can vary by region. For the South, the HIGH site group produced at least 85+ cubic feet/acre/year at culmination of MAI. The MEDIUM site group produced 50-84 cubic feet/acre/year while the LOW site group produced 20-49 cubic feet/acre/year. In the Pacific Northwest-Westside region, the site groups were defined for Hemlock and other species. For Hemlock, the HIGH site group can produce at least 225+ cubic feet/acre/year at culmination of MAI; the MEDIUM site group can produce 120-224 cubic feet/acre/year while the LOW site group can produce 20-119 cubic feet/acre year. For all other species, the HIGH site group produced at least 165+ cubic feet/acre/year; the MEDIUM site group 120-164 cubic feet/acre/year; and the LOW site group produced 20-119 cubic feet/acre/year. Yields can vary markedly by site groups, and any refinements in FASOM classification of site ratings will depend heavily on related developments in ATLAS's handling of productivity measures.

B1.5 MANAGEMENT INTENSITY CLASSES (MIC)

FASOM has four different management classes or regimes that dictate how cohorts are managed in the model.

LO-LO	Lowest management intensity
LO	Low management intensity class
ME	Medium management intensity class
HI	High management intensity class.

The LO, ME, and HI MICs were derived from ATLAS management intensity classes from the 1993 RPA Assessment Update (Haynes et al., 1994b). The management regimes within a MIC varies across regions. In the RPA Assessment Update, for the ATLAS model five alternative management intensities were developed for pine plantations in the Southcentral and Southeastern regions, and for the Douglas-fir and western hemlock types in the Pacific Northwest - Westside subregion. These are:

Pacific Northwest - Westside Subregion

1. Yields represent the current average growth rate for all stands
2. Plantation establishment of 400 trees per acre
3. Plantation establishment and practice precommercial thinning
4. Plantations established with genetically improved seedlings, practice precommercial thinning, and fertilize 10 years prior to harvest
5. Plantation established with genetically improved seedlings, practice precommercial thinning, commercial thin and fertilize 10 years prior to final harvest.

South

1. Regular planting stock without thinning
2. Regular planting stock with commercial thinning
3. Genetically improved planting stock without thinning
4. Genetically improved planting stock with thinning
5. Genetically improved planting stock without thinning but with the most intensive site preparation and management practices.

For the Pacific Northwest-Westside region, FASOM MIC LO was equivalent to ATLAS MIC #1; FASOM MIC ME was equivalent to ATLAS MICs #2 and #3; while FASOM MIC HI is equivalent to ATLAS MICs #4 and #5. For the South, all Natural Stand stands were placed in FASOM MIC LO while ATLAS MICs #1 and #3 were placed in FASOM MIC ME and ATLAS MICs #2, #4, and #5 were placed in FASOM MIC HI.

In all other regions, ATLAS places all timberland acres in the LO MIC or MI #1, thereby assuming that all acres are naturally regenerated and receive no significant intermediate treatments before final harvest. Likewise, in the regions outside the South and the PNWW, ATLAS currently only uses one aggregate site class.

The LO-LO MIC was added to the ATLAS-based MICs to represent future harvested acres that are totally passively managed, where the owner accepts whatever type and rate of regeneration occurs naturally. Relative to the LO MIC, future merchantable timber yields for the LO-LO MIC are lagged 10-years and are some proportion of the LOW timber yields for that same site class and forest type, depending on the region.

B1.6 PRODUCTS

Finally, the following products (PRODS) associated with the forest sector are defined:

SAWTSW	Softwood sawtimber products
PULPSW	Softwood pulpwood products
FUELSW	Softwood fuelwood products
SAWTHW	Hardwood sawtimber products
PULPHW	Hardwood pulpwood products
FUELHW	Hardwood fuelwood products.

The allocation of products can vary by region, forest type, site class, MIC, and by age class. The estimates were obtained from the regional FIA units, with most based on analysis of available FIA data and expert opinions of analysts in each region. The product allocations by age class and other descriptors are one set of model inputs that warrant more attention in future studies for empirical verification.

B2.0 DATA FORMAT AND SOURCES

The sources and format of associated data representing forest inventory, timber yields, and timber management costs in FASOM are discussed next in Sections B2.1 through B2.3. More detailed descriptions are provided by Alig et al. (1994). To provide perspective, 358 million acres of private timberland existed in the U.S. in 1992 (Powell et al., 1993). One-half of the private timberland acres are in the South. In addition, 80 percent of the private timberland acre are held by other private owners, although a large percentage of forest land in the Pacific Northwest is owned by the Forest Industry. Finally, hardwood species are the predominant forest species group in the East while softwood species are the primary forest species group in the West.

B2.1 FOREST INVENTORY

Inventory data representing the private timberland base consists of the area by strata described earlier and the merchantable timber volume per acre. FASOM inventory data were derived from the ATLAS inventory estimates for the 1993 RPA Update (Haynes et al., 1994b). The ATLAS data sets are based on over 70,000 inventory plots that are periodically remeasured on nonfederal timberlands by the regional FIA units.

The ATLAS inventory data includes estimates of privately owned timberland (acres) and growing stock yields (cubic feet per acre) for each RPA region by age class, forest type, site class, and management intensity class.[25] Acres within ATLAS age classes were assigned to appropriate FASOM age cohorts. Acres by region which could potentially be converted from crop or pasture land to forest land were included in the CROPFOR and PASTFOR land classes respectively based on Natural Resource Inventory data of the Soil Conservation Service (1989). All other acres were assigned to the FORONLY land class.

In translating from ATLAS to FASOM data sets, for the South it was necessary to aggregate the 5-year age classes in ATLAS to the 10-year age classes used in the FASOM model. Weighted yields for each ATLAS age class within a FASOM age cohort were used for this purpose. The age classes were aggregated as presented in Table B-2.

Table B-2. Age Classes in FASOM and ATLAS

FASOM Age Class	Age	ATLAS Age Class
0	0-9	0
1	10-19	1, 2
2	20-29	3, 4
3	30-39	5, 6
4	40-49	7, 8
5	50-59	9, 10
6	60-69	11, 12
7	70-79	13, 14
8	80-89	15, 16
9	90+	17

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[25] The FASOM starting inventory estimates by owner will not match those in Powell et al. (1993) in some cases because (1) Native American lands are not included in FASOM's Other Private category, and (2) John Mills did not update all the regional ATLAS files for the 1993 RPA Assessment Update as was done for Powell et al. Mills' input files were used in constructing FASOM inventory files and as a result FASOM starting inventory estimates may differ from Powell et al.

For planted pine in the South, ATLAS MICs 1 and 3 were placed in the FASOM ME MIC while ATLAS MICs 2, 4 and 5 were placed in the HI FASOM MIC. All Southeast and Southcentral natural pine from ATLAS was placed in the LO FASOM MIC.

Inventory data for all regions were broken out by land class (CLS) using USDA Soil Conservation Service (SCS) (1989a) National Resources Inventory estimates of other private forestland with medium or high potential for conversion to cropland and pastureland. Estimates of cropland and pastureland acres with medium or high potential for conversion to cropland and pastureland were entered in the FORCROP and FORPAST land classes respectively. The FORCROP and FORPAST acres were assigned to FASOM high or medium site classes. All remaining timberland acres were assigned to the FORONLY land class. Nonstocked acres by region were entered in 0-9 age class.

B2.2 FOREST YIELDS

The FASOM model requires projections of yields for existing stands, reforested stands, and afforested lands. Note that no afforestation yields are given for the Pacific Northwest-Westside region due to the assumption, discussed earlier, that the land base is in equilibrium between forest and agricultural use in this region. Data on existing stand and reforestation yields were obtained from the corresponding ATLAS inputs used in the 1993 RPA Update (Haynes et al., 1994b). The RPA data give yields per acre based on FIA plot data as well as base yield tables for each RPA region broken out by age class, forest type, site class, and timber management intensity class. In FASOM, all timber yields are assumed to remain constant after 90+ years, tied to the FASOM age cohort 90+. Minimum harvest ages in FASOM are drawn as well from the ATLAS inputs used in the 1993 Assessment RPA Update (Haynes et al., 1994b). Minimum harvest ages vary by region, owner, site group, forest type, and MIC.

Yields for afforested lands are derived from yield tables that were updated from Moulton and Richards (1990) and reconciled with Birdsey's (1992a) estimates. The afforestation yield estimates are given by region (defined in Moulton and Richards, 1990) and forest type for both crop and pasture land.

B2.2.1 Existing Stand Yields

The following procedures were used to derive yields for existing stands in the FASOM model.

<u>Step 1</u>: Derive stocking ratio for each management unit (MU) (Mills and Kincaid, 1992):

a) Set up table using base yield table yield estimates (ft^3/acre) from 93 Update MANAGE file. Thinning volumes were added to yields in all periods following the time period suggested by the ATLAS MANAGE file.

b) Set up plot yield table using existing inventory yield (ft^3/acre) data from 93 Update INVEN file.

c) Determine stocking ratio for current time period:

$S_{it} = V_{it}/Y_{it}$ for each MU by management class

where S_{it} = stocking ratio
for age class = i and time period = t,
V_{it} = existing inventory volume/acre, and

Y_{it} = base yield table volume/acre.

In the South, for each ATLAS MU, volume/acre for FASOM age classes 1-8 was determined using a weighted average of acres within the ATLAS age classes (1-17) associated with each FASOM age cohort. If there was no inventory for an MU within a given FASOM age cohort, the yield for the age cohort was assumed to be the mean volume/acre value for the two associated ATLAS age classes.

A sample of stocking ratio derivation methods for existing inventory is provided below in Table B-3 for the Rocky Mountain region, Foronly land class, Other Private ownership class, Hardwood forest type, Medium site class and Low management intensity class (landid = 612221) at age cohort 40to49 in time period Now.

Table B-3. Example of Stocking Ratio Derivation in FASOM

FASOM Landid Class	ATLAS Management Unit[26]	Plot Yield (ft^3/acre)	Base Yield (ft^3/acre)	Stocking Ratio
612221	91450	884	1159	0.7626
	92450	557	984	0.566

Step 2: Apply relative density change (rdc) coefficients using full and half linear[27] approach to normal equations as appropriate:

Full Approach: $S_{i+1,t+1} = b_1 + b_2{*}S_{it}$.

Half Approach: $S_{i+1,t+1} = (S_{it} + b_1 + b_2{*}S_{it})/2$.

An example of deriving stocking ratios for future time periods is given in Table B-4 for landid class 612221. The rdc coefficients associated with landid class 612221 are $b_1 = 0.193$ and $b_2 = 0.729$,

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[26] The ATLAS Management Units are defined as follows:
91450 = Rocky Mountain region x North subregion x Farmer/Other Private owner x Hardwood forest type; 92450 = Rocky Mountain region x South subregion x Farmer/Other Private owner x Hardwood forest type.

[27] Quadratic form equations were used in the Northcentral regions (Lake States and Corn Belt).

which were derived from 1993 RPA Assessment Update ATLAS input decks. The projected stocking ratios were generated using the full approach to normal equation given above.

Table B-4. Example for Deriving Stocking Ratios for Future Time Periods

Time Period	Age Cohort	Stocking Ratio MU=91450[28]	Stocking Ratio MU=92450
Now	40to49	0.7626	0.5660
+10	50to59	0.7490	0.6056
+20	60to69	0.7390	0.6345
+30	70to79	0.7317	0.6555
+40	80to89	0.7264	0.6709
+50	90+	0.7226	0.6821

Stocking ratios for each MU were determined for each time period and age class using the appropriate rdc coefficients and relative density change equation. Stocking ratios were arranged by ATLAS management unit and time period. If stocking ratios in time period Now exceeded 1.2, they were set equal to 1.2 while if stocking ratios in time periods after time period Now were greater than 1.5, they were set equal to 1.5.

Step 3: Yields (ft^3/acre) were estimated for existing stands by age class over time using the following formula:

$$V_{i+1,t+1} = S_{i+1,t+1} * Y_{i+1}$$

where V = volume/acre for age class i+1 and time period t+1,
S = rdc coefficient for age class i and time period t, and

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[28] Stocking Ratios for time periods after Now are derived using the formula $SR_{t+1} = 0.193 + 0.729 * SR_t$ for MUs 91450 and 92450.

Y = base yield for age class i+1.

In the South, the ATLAS base yield estimates from the MANAGE input file (5-year age classes) were aggregated into FASOM age cohorts (10-year age cohorts) using weighted averages of the percentage of acres in each ATLAS age class associated with a given FASOM age cohort. These percentages were multiplied by the ATLAS base yield table volumes and aggregated by FASOM age cohort. The weighted yield estimates were arrayed by MU and FASOM age cohort. FASOM existing yields by ATLAS management unit were the product of ATLAS base yields by age cohort and associated stocking ratios. An example for management unit 91450 of landid class 612221 is given In Table B-5.

Table B-5. Example Information for Building FASOM Yield Tables: Stocking Ratio Adjustment

Time Period	Age Cohort	Stocking Ratio MU=91450	Base Yields MU=91450	Existing Yield MU=91450
Now	40to49	0.7626	1159	884
+10	50to59	0.7490	1740	1303
+20	60to69	0.7390	2303	1702
+30	70to79	0.7317	2566	1878
+40	80to89	0.7264	2748	1996
+50	90+	0.7226	2867	2072

To obtain aggregate existing yield projections, weighted yields for each ATLAS MU were aggregated using the weighted yield of each management unit associated with each FASOM landid class. Note that the weights of each MU (by age cohort) within a FASOM aggregate class vary by age but not over time. The final aggregate existing yield estimates for each FASOM landid class are the sum of the weighted yields by age cohort over time for all MU's within a FASOM landid class. For landid class 612221, two-thirds of existing acres for age cohort 40to49 are in MU 91450 while the remaining one-third are in MU 92450. Thus, for landid 612221, aggregate existing yields would be computed as in Table B-6.

Next, aggregate existing yields are broken out by softwood and hardwood components. Softwood percentages are derived from softwood percentage estimates given in the ATLAS MANAGE input file. In the South, softwood percentages for each management unit are determined in a manner similar to the weighted existing yields with ATLAS age class softwood percentages aggregated into FASOM age cohorts. Softwood percentages are weighted based on the percentage of acres within each management unit and age class. Weighted softwood proportions[29] for each management unit are then aggregated by FASOM modeling cell. Weighted softwood proportions are arrayed by modeling cell and age cohort over time. Aggregate softwood and hardwood yields by FASOM modeling cell are the product of the aggregate existing yield estimates and the associated aggregate softwood (hardwood) percentage estimates by age cohort and time period.

Table B-6. Example Information for Building FASOM Yield Tables: Weighted Yield Adjustment

Time	Age	Existing Yield MU=91450	Existing Yield MU=92450	Weighted Yield[30] MU=91450	Weighted Yield MU=92450	Aggregate Existing Yield[31]
Now	40to49	884	557	592	184	776
+10	50to59	1303	877	873	289	1163
+20	60to69	1702	1166	1140	385	1525
+30	70to79	1878	1424	1258	470	1728
+40	80to89	1996	1656	1337	546	1884
+50	90+	2072	1865	1388	615	2003

Then, existing softwood and hardwood yields are broken out by softwood and hardwood products (sawtimber, fuelwood, and pulp) with the percentage of softwood and hardwood going to sawtimber,

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[29] Note that hardwood percentages are derived as 1 - sw% for each age and time period by FASOM landid class.

[30] Weights were determined by the number of acres of existing inventory for each mu within a landid class. For landid class 612221, mu 91450, age 40to49 had 100,164 acres while mu 92450, age 40to49 had 49,304 acres. Thus the weights were 0.67 for mu 91450 and 0.33 for mu 92450.

[31] Aggregate existing yield is the sum of weighted existing yields for each mu within a landid class.

pulp, and fuelwood determined based on estimates provided by USDA Forest Service FIA sources. The percentage estimates were provided by fiber type (softwood or hardwood) and age cohort for each product in the model. The yield/acre for each product was derived by simply taking the product of the aggregated softwood (or hardwood) yields and the associated product percentages for each FASOM cell and age cohort over time.

In the first version of the model, time constraints led to several approximations pertaining to growth and yield and growing costs. Commercial thinning volumes were added to base yield volume estimates, starting at the age when thinning volumes first arise, in the two southern regions and the Pacific Northwest-Westside for derivation of existing and regenerated stand yield tables. Once again, these are the only three regions with timber management intensities other than "Low."

Yields for existing and reforested stands in the LOW MIC were derived from the base yield tables (including thinning), relative density change ("approach to normal") equations and regeneration stocking ratios. Stocking ratios for existing stands for time period NOW were the ratio of plot yield to base yield table values by age cohort from the 1993 RPA Update ATLAS input decks while regeneration stocking ratios (rsr's) for regenerated stands (in the LOW MIC) were derived from coefficients given in the ATLAS inputs.

B2.2.2 Regenerated Stand Yields

Regenerated stand yields were derived from base yield tables in the ATLAS MANAGE input file for the 1993 RPA Update. For ATLAS management units with a low management intensity class (naturally regenerated forests), yields were derived using regeneration stocking ratios (rsr's) from ATLAS inputs. Stocking ratios for age cohorts 10to19, 20to29, etc. were derived using "approach to normal" equations and the relative density change coefficients used in deriving FASOM existing stand yields. If the regeneration stocking ratio at age 0to9 exceeded 1.2, the stocking ratio was set equal to 1.2 while stocking ratios in ages 10to19, 20to29, etc. which exceeded 1.5 were set equal to 1.5. Aggregate regenerated stand yields for the LO MIC were the product of the weighted average of base yield table values for ATLAS management units within each corresponding FASOM cell and associated stocking ratios by age cohort. Aggregate yields were broken out by softwood and hardwood products to form the FORONLY, FORCROP, and FORPAST yields.

For regenerated stands with a medium or high FASOM management intensity class, stands were assumed to be fully stocked (the stocking ratio for any age cohort was equal to one). For these stands, the aggregate regenerated stand yields were simply the weighted average of base yield table values for ATLAS management units within each FASOM cell. The aggregate regenerated stand yields for the ME and HI MICs were then broken out by softwood and hardwood products.

Regenerated stand softwood and hardwood yields were determined using the aggregate softwood or hardwood percentages used to derive existing stand softwood and hardwood yields. Regenerated stand product yields were derived using the percentages used to develop existing stand yield tables. Regenerated stand yields for ages over 90+ were assumed constant. Regenerated stand yields were assumed to be equivalent for the FORONLY, FORCROP, and FORPAST land classes.

B2.2.3 Afforested Land Yields

Afforestation yields were derived from Birdsey (1992a) and Moulton and Richards (1990). Birdsey gives yields (cubic feet per acre) by Moulton and Richards (1990) region and forest type for crop and pasture land. These yields were assumed to represent the low FASOM site class while for the Southeast, Southcentral and Pacific Northwest-Westside regions, medium and high site class yields were determined using inflation factors derived from ATLAS base yield tables for equivalent forest types by region. Forest types by region were determined using Birdsey's (1992a) estimates of forest types planted by state, national tree planting data (USDA Forest Service, 1992) and expert opinion. Forest types planted on marginal crop and pastureland by region are given in Table B-7.

Table B-7. Forest Types Used to Construct Afforestation Yields

FASOM Region	Forest Type
North East	Red/White Pine Spruce Southern Pine
South Central	Southern Pine
South East	Southern Pine
Lakes States	Red/White Pine
Corn Belt	Mixed Hardwoods Mixed Softwoods
Rocky Mountains	Ponderosa Pine
Pacific Southwest	Douglass Fir Ponderosa Pine
Pacific Northwest-W	Douglass Fir
Pacific Northwest-E	Ponderosa Pine

All afforested acres were assumed to be fully stocked in terms of ATLAS yield standards. Thus, yields were derived directly from Birdsey's yield tables for those regions in which only one species was planted. Weighted afforestation yields were derived for the Northeast and Pacific Southwest (PSW) regions based on planting percentages by forest type given in Birdsey and NIPF planting statistics (USDA, 1992). In addition, PSW afforestation yields for the low management intensity class were assumed to be 0.76 of Douglas Fir yields in Birdsey's "Pacific" region. The "Pacific" region Douglas Fir yields were used to derive the FASOM PNWW region afforestation yields while the "Pacific" region Ponderosa Pine yields were used to derive FASOM PNWE afforestation yields. Cropland planted to forest was assigned a high FASOM site class while acres planted on pastureland were assigned a medium site class. Afforestation yields for FASOM age cohort "0to9" was the mean of Birdsey age class "0" and "5" while yields for FASOM age cohort "90+" were the average of Birdsey's age classes "95" and "105". Finally, afforestation yields were assumed constant after age cohort 90+.

No commercial thinning volumes were included in deriving afforestation yield tables. Afforestation yields for ME and HI MICs were derived by using ratios of ME to HI MIC yields for regenerated lands from ATLAS for the forest types assumed planted by region.

Afforestation softwood and hardwood yields were determined using the softwood percentages used to derive existing stand softwood and hardwood yields.[32] Finally, afforestation product yields were derived from percentages used to develop existing stand yield tables. Afforestation yields are given for the land classes CROPFOR and PASTFOR.

B2.3 FOREST ESTABLISHMENT/LAND CONVERSION AND MANAGEMENT COSTS

FASOM cost tables were developed for major forestry activities. These activities include costs of stand establishment (including conversion costs associated with planting agricultural land to trees), intermediate treatment or maintenance, harvest and hauling of timber from a stand. Taxes were not included in the forestry costs in order to keep them consistent with cost accounting on the longer-standing agricultural side of FASOM.

FASOM tables associated with forest establishment costs and intermediate management costs were derived from a variety of data sources (Alig et al., 1994). Establishment costs include costs of site

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[32] In the FASOM Corn Belt region softwood percentages suggested by Birdsey were used to generate afforestation softwood and hardwood yields.

preparation, planting, and conversion (land clearing, wind rowing, burning, etc.) while intermediate management costs include costs of thinning, prescribed burning, timber cruising, road maintenance, and other costs. The management costs are decadal averages in the first-generation FASOM model and in the next model version an attempt will be made to build in point estimates for intermediate management costs.

Establishment costs vary by FASOM land class (CLS), with generally higher costs for reforested acres, such as those on for FORONLY acres, and lower costs for afforesting CROPFOR and PASTFOR acres. A prohibitive cost estimate of 999.999 value was used to ensure that selected management options were not selected (such as LO MIC for afforestation, as currently configured).

Cost estimates were also assembled for converting timberland to cropland or pastureland. Sources were various Economic Research Service studies and expert opinion. However, most of the formal studies were dated, with most conducted before the 1980s and before significant changes in conversion technology, and so were augmented by expert opinion. To reflect different levels of conversion costs due to site, topography, drainage, and other factors, three levels of costs were used to represent a step function or increasing marginal costs of conversion as more timberland is converted. Costs include that for land clearing, wind rowing, burning, etc. and any necessary leveling and removing large chunks for seedbed preparation. Any timberland converted to agricultural land is assumed to occur after harvest of any merchantable trees, and 75% of timber volume removed in land clearing is assumed to be hauled to market.

B2.3.1 Relationship of FASOM Inventory, Yield, and Cost Tables

Any stand can be regenerated or converted to an agricultural use after harvest or at any time in its span of existence if it is grouped in the lowest management intensity class. The allocation selected is based on the net present value of the alternative uses (forest, crop, and pasture). In addition, the FASOM model will select among the alternative management intensities when regenerating a stand. As before, the most profitable option will involve consideration of supply and demand conditions, prices, yields and costs. Yields associated with regenerated stands are arrayed by forest product, region, land class, owner, site class, management intensity and age cohort. If a stand is converted to an agricultural use, it may be converted back to forestry in future time periods if it is more profitable to do so. Yields associated with such afforested stands are given for land classes CROPFOR and PASTFOR (Alig et al., 1994).

B3.0 LAND USE CHANGES INVOLVING FORESTRY

The competition for land between the forestry and agricultural portions of FASOM, as well as the shift of some timberland to urban and developed uses, necessitates explicit considerations of pathways for land coming in and out of forestry in the FASOM modeling. Through the land class definitions used to describe the INVENTORY acres, described above, we identify other private timberland acreage that could potentially be converted to cropland and pastureland; or vice versa, agricultural land that could be shifted into forestry.

The land class definitions allow us to distinguish area of agricultural land converted actively to timberland (i.e., agricultural land planted to trees) vs. that converted to agricultural uses from timberland.[33] We also constrain cropland-forestry land use shifts to the high site group, and pastureland-forestry shifts to the medium site group.[34] From the forestry side, the timber yields on land suitable for agricultural do not differ from those for the corresponding FORONLY cells. When forest land is shifted to agriculture, it is assumed that the timberland converted to cropland was in the high site group for other private timberland. Further, associated timber yields for actively afforested land are aligned with unique afforestation site ratings, e.g., high site for afforested land has higher productivity than for high site FORONLY land.

Afforestation enrollments are placed into either the medium or high MICs depending on the FASOM relative profitability computations. By definition, afforested acres are precluded from being placed in the low MIC since the afforested acres are assumed to be planted.

Conversion between forestry and agricultural land uses takes place in FASOM when the present value of expected land rents in agricultural uses exceed those from timber growing, or vice versa. The INVENTORY accounting reflects constraints that only a specified percentage of other private timberland, by region, could be converted to cropland or pastureland over the 100-year FASOM horizon. When an afforested stand is harvested, the options for the next time period include replanting to obtain the same timber yields over the rotations as for the first afforested stand. In contrast, FASOM also has the option of placing the harvested afforested acreage into the low MIC class, where natural regeneration at lower cost takes place. It logically wouldn't enroll harvested afforested stands into the ME or HI MICs for FORONLY because the timber management costs would be essentially identical to that for afforested land but with lower timber yields at corresponding ages. For the other

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[33] The possibility of passive reversion of ag. land to timberland is being considered for incorporation in future versions of FASOM. For example, idle agricultural land in some regions of the country would be candidates to slowly revert to tree cover under certain circumstances. In those cases, timber yields on naturally reverting land would be discounted and lagged relative to naturally regenerated FORONLY yields.

[34] A related assumption is that timberland acres can not shift across site groups over the projection period, i.e., acres remain in the same site group.

private owner group, timber yields for timberland are potentially spread across five LANDCLASS categories; however, for FORONLY, FORCROP, and FORPAST the timber yields are identical for corresponding cells.

The amount of rangeland suitable for tree planting is assumed to be insignificant, as is the amount of timberland likely to be converted to rangeland.

Constraints on the amount of timberland that could be converted to agricultural uses were derived from data from the Natural Resource Inventory by SCS (1989), pertaining to other private forestland with medium or high potential for conversion to cropland and pastureland. The data were checked against that for prime farmland defined on p. 21 of The Second RCA Appraisal, representing forest, pastureland, cropland, rangeland, or other minor land uses that have good potential for cultivated crops (e.g., slope less than 5%, not excessively eroded, not wetlands, etc.). The published SCS data does not identify forestland qualifying as prime cropland below our FASOM region, thus allocation of prime cropland by forest type, MIC, and age cohort is by assumption (proportional to what is in the highest forestry site group).

B3.1 EXOGENOUS LAND TRANSFERS

Two primary types of exogenous land transfers into and out of forestry in the current FASOM model are: 1) tree planting due to government programs; and 2) transfers to urban and other developed uses. Tree planting due to government programs was enrolled each decade by region, for reforestation and afforestation. Estimates were based on RPA Land Base analyses (Alig et al., 1990b), tree planting reports by State and Private Forestry, and personal communication with State and Private Forestry staff.

Projected exogenous levels of other private timberland converted to urban and developed uses were incorporated by region, based on considerations of projected changes in population and personal income (Alig et al., 1990b). For forest industry, no net change in timberland area was assumed in this modeling phase. This means that the amount of other private timberland acquired by forest industry will offset the conversion of some forest industry land to urban and developed uses. Acres are assumed to exit the timberland base by age cohort in proportion to the total timberland area by age cohort.

B4.0 FORESTRY GLOSSARY

Age cohort - Timber stands are grouped by their average age, i.e., years since origin (either natural seeding or plantation). Since trees in a given stand can vary in their ages, a stand's age is the class that best characterizes the stand. In FASOM, 10-year age cohorts are employed; 0-9 years is called age cohort 1, 10-19 years is called age cohort 2, and so on.

ATLAS - Aggregate Timberland Assessment System (Mills and Kincaid, 1992) that has been used in RPA Timber Assessments to project timber growth and yield via linkage with the TAMM model to reflect harvests, and account for timberland area changes via interaction with area change models. ATLAS-related information was incorporated where appropriate in FASOM's forestry sector.

Base yield table - input yield table in ATLAS input decks for RPA Assessment. The yields are derived based on empirical data as well as from forest growth models.

Crop land - Land used for the production of adapted crops for harvest including row crops, small grain crops, hay crops, nursery crops, orchard crops, and other specialty crops. The land may be used continuously for these crops, or they may be grown in rotation with grasses and legumes.

Forest Inventory and Analysis (FIA) - Regional research work units of the USDA Forest Service that conduct period surveys of the nation's forest resources. Data on forest growth, harvest, and renewal are collected to support a number of private and public analyses, including information compiled for the 1992 Resources Planning Act (RPA) Assessment Update (Powell et al., 1993).

Forest industry ownership class - A diverse group of forest products manufacturers with processing facilities that own timberland.

Forest land - Land at least 10% stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated.

Forest type - A classification of forest land based upon the species presently forming a plurality of the live-tree stocking. FASOM softwood and hardwood forest types are aggregations of ATLAS and FIA forest types.

Fuelwood - wood used by conversion to some form of energy, primarily residential use.

Growing stock volume - Net volume in cubic feet of live poletimber and sawtimber trees, including all live trees larger that 5 inches in dbh except cull trees. Volume is measured from a one-foot high stump to a minimum 4-inch top (of central stem) outside the bark. Net volume equals gross volume less deduction for rot and missing bole sections.

Hardwood - A dicotyledonous tree, usually broad-leaved and deciduous.

Major Eastern Forest Type Groups

White-red-jack pine - Forests in which eastern white pine, red pine, or jack pine, singly or in combination comprise a plurality of the stocking. Common associates include hemlock, aspen, birch, and maple.

Spruce-fir - Forests in which spruce or true firs, singly or in combination comprise a plurality of the stocking. Common associates include white cedar, tamarack, maple, birch, and hemlock.

Longleaf-slash pine - Forests in which longleaf or slash pine, singly or in combination comprise a plurality of the stockings. Common associates include other southern pines, oak and gum.

Loblolly-shortleaf pine - Forests in which loblolly pine, shortleaf pine, or southern yellow pines, except longleaf or slash pine, singly or in combination comprise a plurality of the stocking. Common associates include oak, hickory, and gum.

Oak-pine - Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking, but in which pine or eastern red cedar comprises 25-50% of the stocking. Common associates include gum, hickory, and yellow-poplar.

Oak-hickory - Forests in which upland oaks, or hickory, singly or in combination comprise a plurality of the stocking except where pines comprise 25-50%, in which case the stand would be classified as oak-pine. Common associates include yellow-poplar, elm, maple, and black walnut.

Oak-gum-cypress - Bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination comprise a plurality of the stocking except where pines comprise 25-50%, in which case the stand would be classified as oak-pine. Common associates include cottonwood, willow, ash, elm, hackberry, and maple.

Elm-ash-cottonwood - Forests in which elm, ash, or cottonwood, singly or in combination comprise a plurality of the stocking. Common associates include willow, sycamore, beech, and maple.

Maple-beech-birch - Forests in which maple, beech, or yellow birch, singly or in combination comprise a plurality of the stocking. Common associates include maple and balsam fir.

Aspen-birch - Forests in which aspen, balsam poplar, paper birch, or gray birch, singly or in combination comprise a plurality of the stocking. Common associates include maple and balsam fir.

Major Western Forest Type Groups

Douglas-fir - Forests in which Douglas-fir comprises a plurality of the stocking. Common associates include western hemlock, western red cedar, the true firs, redwood, ponderosa pine, and larch.

Hemlock-Sitka spruce - Forests in which western hemlock and/or Sitka spruce comprise a plurality of the stocking. Common associates include Douglas-fir, grand fir, and tanoak.

Redwood - Forests in which redwood comprises a plurality of the stocking. Common associates include Douglas-fir, grand fir, and tanoak.

Ponderosa pine - Forests in which ponderosa pine comprises a plurality of the stocking. Common associates include Jeffrey pine, sugar pine, limber pine, Arizona pine, Apache pine, Chihuahua pine, Douglas-fir, incense cedar, and white fir.

Western white pine - Forests in which white pine comprises a plurality of the stocking. Common associates include western red cedar, larch, white fir, Douglas-fir, lodgepole pine, and Engelmann spruce.

Lodgepole pine - Forests in which lodgepole pine comprises a plurality of the stocking. Common associates include alpine fir, western white pine, Engelmann spruce, aspen, and larch.

Larch - Forests in which western larch comprises a plurality of the stocking. Common associates include Douglas-fir, grand fir, western red cedar, and western white pine.

Fir-spruce - Forests in which true firs, Engelmann spruce, or Colorado blue spruce, singly or in combination comprise a plurality of the stocking. Common associates include mountain hemlock and lodgepole pine.

Management intensities - timberland management categories developed for the Aggregate Timberland Assessment System (ATLAS) to represent the development of stands under various improved management practices. FASOM's three management classes are aggregations of ATLAS's five alternative management intensities. ATLAS's maximum number of classes were developed for pine plantations in the Southcentral and Southeastern regions, and for the Douglas-fir and western hemlock types in the Pacific Northwest - Westside subregion. These are:

Pacific Northwest - Westside Subregion

1. Yields represent the current average growth rate for all stands
2. Plantation establishment of 400 trees per acre
3. Plantation establishment and practice precommercial thinning

4. Plantations established with genetically improved seedlings, practice precommercial thinning, and fertilize 10 years prior to harvest
5. Plantation established with genetically improved seedlings, practice precommercial thinning, commercial thin and fertilize 10 years prior to final harvest.

South

1. Regular planting stock without thinning
2. Regular planting stock with commercial thinning
3. Genetically improved planting stock without thinning
4. Genetically improved planting stock with thinning
5. Genetically improved planting stock without thinning but with the most intensive site preparation and management practices.

Marginal crop and pasture land - Cropland and pasture that could yield higher rates of return to the owner if planted to pine or those other trees.

Natural pine - Forests in which 50% or more of the naturally established stand is loblolly pine, slash pine, shortleaf pine, longleaf pine, or other southern pines singly or in combination. Common associates include oak, hickory, and gum.

Net annual growth - The net increase in the volume of trees during a specified year. Components include the increment in net volume of trees at the beginning of the specific year surviving to its end, plus the net volume of trees reaching the minimum size class during the year, minus the volume of trees that died during the year, and minus the net volume of trees that became cull trees during the year.

Net volume in board feet - The gross board-foot volume of the sawlog portion of live sawtimber trees less deductions for rot or other defects affecting use of lumber.

Net volume in cubic feet - The gross volume in cubic feet less deductions for rot, roughness, and poor form. Volume is computed for the central stem from a 1-foot stump to a minimum 4.0 inch top diameter outside bark, or to the point where the central stem breaks into limbs.

Other private - All private owners other than forest industry, and the diverse group includes farmers.

Pacific Northwest - Eastside - The area in the states of Oregon and Washington that is east of the crest of the Cascade Range.

Pacific Northwest - Westside - The area in the states of Oregon and Washington that is west of the crest of the Cascade Range.

Pasture land - Agricultural land holding improved grass or other vegetation eaten by grazing farm animals, in contrast to natural vegetation of rangeland category.

Productivity class - A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment in fully stocked natural stands.

Pulpwood - Roundwood, whole-tree chips, or wood residues that are used for the production of woodpulp.

Relative density change - stocking adjustment for timber stands which moves the density of an existing stand over time relative to that of a reference yield.

Regeneration stocking ratio - represents the average stocking of the regenerated timber stand relative to the reference yield table.

Sawlog - A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards. A log usually used in the manufacture of lumber.

Sawtimber - Stands at least 10% occupied with growing stock trees, with half or more of total stocking in sawtimber or poletimber trees, and with sawtimber stocking at least equal to pole-timber stocking.

Site productivity - A measure of inherent capability of land to grow timber based on fully stocked natural stands.

Softwood - A coniferous tree, usually evergreen, having needles or scalelike leaves.

Stocking - The degree of occupancy of land by trees, measured by basal area and/or number of trees by size and spacing, compared to a stocking standard; i.e., the basal area and/or number of trees required to fully utilize the growth potential of the land.

Stumpage - Standing timber (trees) in the forest.

Stumpage price - The price paid for standing timber in the forest.

Timber removals - The net volume of growing stock trees removed from the inventory by harvesting; cultural operations, such as timber stand improvement; land clearing; or changes in land use.

Timberland - Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. Areas qualifying as timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included if they meet the productivity requirements and are not withdrawn.

APPENDIX C

CURRENT GAMS LISTING OF FASOM MODEL EQUATIONS

The purpose of this appendix is to present a listing of the GAMS file FAMODEL. FAMODEL contains the basic structure of the model and is the "core" file for the FASOM modeling system from which other program and data files are called. The file structure in FASOM is discussed in greater detail in Appendix D.

```
$ontext
fasom model component famodel
```

Version as of Jan 24, 1994

```
$OFFTEXT
YESAG=1;YESFOR=1;

$include "fapoldat"
$include "famodset"
sepfor = 1;
sepag  = 1;
set       dir /fromag,toag/
PARAMETER YESsite(cls,site,dir ) identify land transfer types
                /cropfor.hi.fromag 1 , pastfor.me.fromag 1,
                 forcrop.hi.toag 1 , forpast.me.toag 1,
                 cropfor.hi.toag 1 , pastfor.me.toag 1/
parameter whentran(reg,cls,site,owner,spec,dir) identifies when land transfer allowed;
whentran(regs,cls,site,"op",spec,"toag")$yessite(cls,site,"toag")=1$(
           SUM(THREE,CONVERT(REGS,CLS,"CCOST",THREE)) GT 0
           AND
      SUM((SPMAPPR(SPECIES,SPEC),MIC,WHEN2),
                ISNEW(REGS,CLS,"op" ,SPECIES,site,MIC,WHEN2)) GT 0) ;
whentran(regs,cls,site,"op",spec,"fromag")$yessite(cls,site,"fromag")
     =1$ (
*  SUM(THREE,CONVERT(REGS,CLS,"CCOST",THREE)) GT 0
*          AND
   SUM((SPMAPPR(SPECIES,SPEC),MIC,WHEN2),
                ISNEW(REGS,CLS,"op" ,SPECIES,site,MIC,WHEN2)) GT 0);
whentran("pnww",cls,site,owner,spec,dir)=0;
*whentran("gp",cls,site,owner,spec,dir)=0;
*whentran("sw",cls,site,owner,spec,dir)=0;
*whentran(reg,"forcrop",site,owner,spec,"fromag")=0;
*whentran(reg,"forpast",site,owner,spec,"fromag")=0;
*whentran(reg,cls,site,"fi",spec,dir)=0;
*whentran(reg,"cropfor","lo","op",spec,dir)=0;
*whentran(reg,"cropfor","me","op",spec,dir)=0;
*whentran(reg,"pastfor","lo","op",spec,dir)=0;
*whentran(reg,"pastfor","hi","op",spec,dir)=0;
*display isnew,whentran;
*   =============================================================

*                       MODEL DEFINITION

*   =============================================================


*   ^^^^^^^^^^^^^^^^^^^^

* SPECIFY NAMES OF VARIABLES WHICH ARE RESTRICTED IN SIGN

*   ^^^^^^^^^^^^^^^^^^^^

POSITIVE VARIABLES

 EXIST(REG,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN) AREA CUT FROM EXISTING STANDS
*                                                 "WHEN" = AGE AT HARVEST
*                                                  UNITS 1,000 ACRES

 NEW(REG,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECS,policy) REESTABLISHMENT ACTIVITY
*                                             "WHEN" = AGE AT HARVEST
*                                             "DECS" = DECADE OF ESTABLISHMENT
*                                              UNITS 1,000 ACRES

 BUILDCAP(PRODS,DECS)                        BUILD FOREST CAPACITY
 DEMANDFOR(PRODS,DECS)                       FOREST PRODUCT DEMAND( MMCF)
 DEMANDFORS(PRODS,DECS,STEPS)                FOREST PRODUCT DEMAND( MMCF) SEPERABLE
 PRODUCTSUB(PRODS,PRODS,DECS)                FOREST PRODUCT SUBSTITUTION(MMCF)
 TRANSFOR(REG,PRODS,DECS)                    FOREST PRODUCT TRANSPORT ( MMCF)
 TRADEFPTRN(REG,TRADEREG,PRODS,DECS,TRADE)   FOREST PRODUCT TRADE TRANSPORT
 TRADEQUAN(TRADEREG,PRODS,DECS,TRADE)        QUANTITIES TRADED OF FOR PROD
 TRADEQUANS(TRADEREG,PRODS,DECS,TRADE,STEPS) QUANTITIES TRADED OF FOR PROD SEPERABLE
 LANDFROMAG(REG,CLS,DECS)                    LAND GOING INTO FORESTRY(M ACRES)
 LANDTOAG(REG,CLS,DECS,THREE)                LAND GOING INTO AG( M ACRES)
 CONVRTTOAG(REG,CLS,DECS,SPEC)   FOREST LAND CONVERTED TO AG(M ACRES)
 CONVRTFRAG(REG,CLS,DECS,SPEC)   AG LAND CONVERTED TO FOREST(M ACRES)
 COSTS(REG,DECS)                             UNDISCOUNTED VALUE OF FORESTRY COSTS ($ 1990 MILLIONS)
 TERMVOLN(PRODS)                             TERMINAL VOL. OF FOREST INV. (MMCF)
 TERMVOLNS(PRODS,STEPS)                      TERMINAL VOL. OF FOREST INV. (MMCF) SEPERABLE
 FUELSUB(REG,DECS)                           FUELWOOD SUBSTITUTION
 ENDFUELSUB(REG)                             TERMINAL FUELWOOD SUBSTITUTION
 CARBONSE(DECS)                              CARBON SEQUESTERED

*ASM PART

CROPBUDGET(DECS,REG,CROP,WTECH,CTECH,TECH)  CROP BUDGETS
LVSTBUDGET(DECS,REG,ANIMAL,LIVETECH)        LIVESTOCK BUDGETS
LANDSUPPLY(DECS,REG,LANDTYPE)               REGIONAL LAND SUPPLY
LANDSUPPLS(DECS,REG,LANDTYPE,STEPS)         REGIONAL LAND SUPPLY-- SEPERABLE
PROCESS(DECS,PROCESSALT)                    PROCESSING BUDGETS
WATERFIX(DECS,REG)                          FIXED PRICE - FIXED WATER SUPPLY
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WATERVAR(DECS,REG)                          VARIABLE COST - PUMPED WATER SUPPLY
WATERVARS(DECS,REG,STEPS)                   VARIABLE COST - PUMPED WATER SUPPLY-- SEPERABLE
AUMSPUB(DECS,REG)                           PUBLIC FIXED PRICE AUMS SUPPLY
AUMSPRIV(DECS,REG)                          PRIVATE AUMS SUPPLY
AUMSPRIVS(DECS,REG,STEPS)                   PRIVATE AUMS SUPPLY -- SEPERABLE
FAMILY(DECS,REG)                            FAMILY LABOR SUPPLY
HIRED(DECS,REG)                             HIRED LABOR SUPPLY
HIREDS(DECS,REG,STEPS)                      HIRED LABOR SUPPLY-- SEPERABLE
DEMANDP(DECS,PRIMARY)                       PRIMARY PRODUCT DOMESTIC DEMAND
DEMANDPS(DECS,PRIMARY,STEPS)                PRIMARY PRODUCT DOMESTIC DEMAND-- SEPERABLE
IMPORTP(DECS,PRIMARY)                       PRIMARY PRODUCT IMPORTS
IMPORTPS(DECS,PRIMARY,STEPS)                PRIMARY PRODUCT IMPORTS-- SEPERABLE
EXPORTP(DECS,PRIMARY)                       PRIMARY PRODUCT EXPORTS
EXPORTPS(DECS,PRIMARY,STEPS)                PRIMARY PRODUCT EXPORTS-- SEPERABLE
DEMANDS(DECS,SECONDARY)                     SECONDARY PRODUCT DOMESTIC DEMAND
DEMANDSS(DECS,SECONDARY,STEPS)              SECONDARY PRODUCT DOMESTIC DEMAND-- SEPERABLE
IMPORTS(DECS,SECONDARY)                     SECONDARY PRODUCT IMPORTS
IMPORTSS(DECS,SECONDARY,STEPS)              SECONDARY PRODUCT IMPORTS-- SEPERABLE
EXPORTS(DECS,SECONDARY)                     SECONDARY PRODUCT EXPORTS
EXPORTSS(DECS,SECONDARY,STEPS)              SECONDARY PRODUCT EXPORTS-- SEPERABLE
MIXR(DECS,REG,CRPMIXALT)                    CROP MIXES BY REGION
NATMIX(DECS,PRIMARY,NATMIXALT)              PRIMARY PRODUCT MIXES ACROSS REGIONS
CCCLOANP(DECS,PRIMARY)                      PRIMARY PRODUCT CCC LOAN SALES
CCCLOANS(DECS,SECONDARY)                    SECONDARY PRODUCT CCC LOAN SALES
DEFPRODN(DECS,ALLI)                         PRODUCTION RECEIVE DEFIC PYMT
PRDN5092(DECS,ALLI)                         PRODUCTION RECEIVE 5092 PYMT
DIVPRODN(DECS,ALLI)                         PRODUCTION RECEIVE DIVERSION PYMT
ARTIF(DECS,ALLI)                            ARTIFICIAL PRODUCTION
UNHARV(DECS,ALLI)                           UNHARVESTED PRODUCTION

*   ^^^^^^^^^^^^^^^^^^^^

* SPECIFY NAMES OF VARIABLES WHICH ARE UNRESTRICTED IN SIGN

*   ^^^^^^^^^^^^^^^^^^^^

 VARIABLES

  WELFARE                  TOTAL CONSUMERS PLUS PRODUCERS(PRESENT VALUE $1990 MILLION)
  TWID(DEC,CROP,REG)       ALLOWS IMPRECISION IN CROP MIXES
  TOLR(DEC,PRIMARY,REG)    ALLOWS IMPRECISION IN LIVESTOCK MIXES

*   ^^^^^^^^^^^^^^^^^^^^

* SPECIFY EQUATION NAMES

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 EQUATIONS

 WELFAR                                             OBJECTIVE FUNCTION
 INVENTORYA(REG,CLS,OWNER,SPECIES,SITE,MIC,COHORT)  GROWING STOCK INV OF EXISTING STANDS
 LANDBALANC(REG,CLS,OWNER,SITE,DECS,SPEC)           LAND AVAILABLE TO BE FORESTED OR CONVERTED
 sipLANDBAL(REG,CLS,SITE,DECS,SPEC)                 LAND AVAILABLE TO used in sip
 availmoney(policy)                                 money AVAILABLE TO used in sip
 forcedland(policy)                                 landforced in by a policy
 PRODBALSUP(REG,PRODS,DECS)                         FOREST SUPPLY MARKET BALANCE
 PRODBALDEM(PRODS,DECS)                             FOREST DEMAND MARKET BALANCE
 CPRDBALDEM(PRODS,DECS)                             FOREST DEMAND MARKET CONVEX
 CAPACLIM(PRODS,DECS)                               FOREST DEMAND CAPACITY LIMITS
 TRADEBAL(TRADEREG,PRODS,DECS)                      FOREST PRODUCT TRADE BALANCE
 CTRADEBAL(TRADEREG,PRODS,DECS,TRADE)               FOREST PRODUCT TRADE CONVEX
 COSTBAL(REG,DECS)                                  FORESTRY COSTS
 NENDINVEN(PRODS)                                   NAT TERMINAL FOREST INV.
 CNENDINVEN(PRODS)                                  NAT TERMINAL FOREST CONVEX
*LAND TRANSFERS
 TRNtoLDBAL(REG,CLS,DECS)                           LAND to ag  INTERFACE
 TRNfrLDBAL(REG,CLS,DECS)                         LAND to for INTERFACE
 LANDTRNLIM(REG,CLS,THREE)                          LAND CONVERSION LIMIT TO AG
 AGLDTRNLIM(REG,CLS)                                LAND CONVERSION LIMIT FROM AG
*CARBON SECTOR
 CARBON(DECS)                                       SEQUESTERED CARBON

*  ASM PART
    PRIMARYBAL(DECS,PRIMARY)       PRIMARY PRODUCT BALANCE
    CPRIBALDOM(DECS,PRIMARY)       PRIMARY PRODUCT DOMESTIC  -- CONVEXITY FOR SEPERABLE
    CPRIBALIMP(DECS,PRIMARY)       PRIMARY PRODUCT IMPORT  -- CONVEXITY FOR SEPERABLE
    CPRIBALEXP(DECS,PRIMARY)       PRIMARY PRODUCT EXPORT  -- CONVEXITY FOR SEPERABLE
    SECONDBAL(DECS,SECONDARY)      SECONDARY PRODUCT BALANCE
    CSECBALDOM(DECS,SECONDARY)     SECONDARY PRODUCT DOMESTIC -- CONVEXITY FOR SEPERABLE
    CSECBALIMP(DECS,SECONDARY)     SECONDARY PRODUCT IMPORTS -- CONVEXITY FOR SEPERABLE
    CSECBALEXP(DECS,SECONDARY)     SECONDARY PRODUCT EXPORTS -- CONVEXITY FOR SEPERABLE
    MAXLAND(DECS,REG,LANDTYPE)     MAXIMUM LAND AVAILABLE IN A REG
    LAND(DECS,REG,LANDTYPE)        REGIONAL AG LAND BALANCE
    CLAND(DECS,REG,LANDTYPE)       REGIONAL AG LAND BALANCE -- CONVEXITY FOR SEPERABLE
    WATERR(DECS,REG)               REGIONAL WATER BALANCE
    CWATERR(DECS,REG)              REGIONAL WATER  -- CONVEXITY FOR SEPERABLE
    FIX(DECS,REG)                  REGIONAL MAXIMUM FIXED PRICE WATER
    AUMSR(DECS,REG)                REGIONAL AUMS BALANCE
    CAUMSR(DECS,REG)               REGIONAL AUMS BALANCE -- CONVEXITY FOR SEPERABLE
    PUBAUMS(DECS,REG)              MAXIMUM FIXED PRICE PUBLIC AUMS
    LABOR(DECS,REG)                REGIONAL LABOR BALANCE
    FAMILYLIM(DECS,REG)            MAXIMUM FAMILY LABOR
    CLABOR(DECS,REG)               REGIONAL HIRED BALANCE -- CONVEXITY FOR SEPERABLE
    HIRELIM(DECS,REG)              MAXIMUM HIRED LABOR
    MIXREG(DECS,CROP,REG)          CROP MIX CONSTRAINTS BY ACREAGE IN REGION
    MIXREGTOT(DECS,REG)            TOTAL ACRES IN A CROP MIX
    MIXNAT(DECS,PRIMARY,REG)       PRIMARY PRODUCT DISTRIBUTION ACCROSS REGIONS
    FRMPROG(DECS,CROP)             TOTAL FARM PROGRAM PRODUCTION
    P5092(DECS,CROP)               TOTAL 5092 ACREAGE PRODUCTION
    DIVERT(DECS,CROP)              TOTAL VOLUNTARY DIVERSION PRODUCTION
    ARTIFICIAL(DECS,CROP)          ARTIFICIAL FARM PROGRAM PRODUCTION
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    UNHARVEST(DECS,CROP)           PAID BUT UNHARVESTED FARM PROGRAM PRODUCITON
   ;
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*    SPECIFY EQUATIONS

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*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&

*OBJECTIVE FUNCTION

 WELFAR.. WELFARE =E=

SUM(DEC$yesfor, DISC(DEC)*
* FOREST PROCESSING CAPACITY COST
   (- SUM((PRODS)$(CAPACITY(PRODS,"NOWINPLACE") GT 0),
           BUILDCAP(PRODS,DEC)*CAPACITY(PRODS,"COSTNEW"))*SCFOR
* AREA UNDER DOMESTIC FOREST PRODUCT DEMAND CURVE
    +  SUM((PRODS)$FPDEMAND(PRODS,DEC,"SLOPE"),
          ((( - FPDEMAND(PRODS,DEC,"INTERCEPT")/
                FPDEMAND(PRODS,DEC,"SLOPE"))
              + 0.5 * (1/FPDEMAND(PRODS,DEC,"SLOPE"))
               * SCFOR*DEMANDFOR(PRODS,DEC)) *
                 SCFOR*DEMANDFOR(PRODS,DEC))$(SEPFOR LE 0)
     + SUM(STEPS,(((-FPDEMAND(PRODS,DEC,"INTERCEPT")/
                     FPDEMAND(PRODS,DEC,"SLOPE"))
                +  0.5 * (1/FPDEMAND(PRODS,DEC,"SLOPE"))
                 * QINC(STEPS)*DEMANDQ(PRODS,DEC))
                 * QINC(STEPS)*DEMANDQ(PRODS,DEC))
                 * DEMANDFORS(PRODS,DEC,STEPS) )$SEPFOR)
     + SUM((PRODS)$(FPDEMAND(PRODS,DEC,"SLOPE") EQ 0
                   AND FPDEMAND(PRODS,DEC,"FIXP") GT 0),
           FPDEMAND(PRODS,DEC,"FIXP") * DEMANDFOR(PRODS,DEC)*SCFOR)
* AREA UNDER EXPORT FOREST PRODUCT DEMAND CURVE
     + SUM((TRADEREG,PRODS)$TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE"),
         (((- TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"INTERCEPT")/
              TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE"))
            + 0.5 * (1/TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE"))
                 * SCFOR*TRADEQUAN(TRADEREG,PRODS,DEC,"EXPORT"))
                 * SCFOR*TRADEQUAN(TRADEREG,PRODS,DEC,"EXPORT"))$(SEPFOR EQ 0)
     + SUM(STEPS,((-TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"INTERCEPT")/
                    TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE"))
                  + 0.5 * (1/TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE"))
                     * QINC(STEPS)*TRADEQ(TRADEREG,PRODS,DEC,"EXPORT"))
                     * QINC(STEPS)*TRADEQ(TRADEREG,PRODS,DEC,"EXPORT")*
                       TRADEQUANS(TRADEREG,PRODS,DEC,"EXPORT",STEPS))$SEPFOR)
     + SUM((TRADEREG,PRODS)$(TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE") EQ 0
                   AND TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"FIXP") GT 0),
                   SCFOR*TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"FIXP") *
                   TRADEQUAN(TRADEREG,PRODS,DEC,"EXPORT"))
* AREA UNDER IMPORT FOREST PRODUCT DEMAND CURVE
     - SUM((TRADEREG,PRODS)$TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE"),
           (((-TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"INTERCEPT")/
               TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE"))
             + 0.5 * (1/TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE"))
                 * SCFOR*TRADEQUAN(TRADEREG,PRODS,DEC,"IMPORT"))
                 * SCFOR*TRADEQUAN(TRADEREG,PRODS,DEC,"IMPORT"))$(SEPFOR EQ 0)
     + SUM(STEPS,((-TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"INTERCEPT")/
                    TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE"))
                  + 0.5 * (1/TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE"))
                   * QINC(STEPS)*TRADEQ(TRADEREG,PRODS,DEC,"IMPORT"))
                   * QINC(STEPS)*TRADEQ(TRADEREG,PRODS,DEC,"IMPORT")*
                     TRADEQUANS(TRADEREG,PRODS,DEC,"IMPORT",STEPS))$SEPFOR)
     - SUM((TRADEREG,PRODS)$(TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE") EQ 0
                   AND TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"FIXP") GT 0),
                  SCFOR*TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"FIXP") *
                   TRADEQUAN(TRADEREG,PRODS,DEC,"IMPORT"))
* COST OF TRANSPORT FOR DOMESTIC FOREST PRODUCTS
    -  SUM((REGS,PRODS)$(TRANSCOST(REGS,PRODS) NE 0 AND
                        YESITIS(REGS,PRODS) GT 0 )
             ,SCFOR*TRANSCOST(REGS,PRODS)*(TCOSTINF(DEC,REGS))
                   *TRANSFOR(REGS,PRODS,DEC) )
* COST OF TRANSPORT FOR IMPORTED AND EXPORTED FOREST PRODUCTS
     -  SUM((REGS,TRADEREG,PRODS,TRADE)$YESITIS(REGS,PRODS),
             TRADEFPTRN(REGS,TRADEREG,PRODS,DEC,TRADE)$
              (TRADFOR(TRADEREG,TRADE,PRODS,DEC,"INTERCEPT") GT 0  OR
               TRADFOR(TRADEREG,TRADE,PRODS,DEC,"MINQ")      GT 0  OR
               TRADFOR(TRADEREG,TRADE,PRODS,DEC,"FIXP")      GT 0)
             *SCFOR*TRADECOST(REGS,TRADEREG,PRODS)*(TCOSTINF(DEC,REGS)))
* PRODUCTION AND HARVEST COSTS
    -  SUM(REGS,SCFOR*COSTS(REGS,DEC))
* A SMALL COST FOR DOWNWARD PRODUCT SUBSTITION
     -  SUM((PRODUCTS,PRODS)
          ,SCFOR*0.1*PRODUCTSUB(PRODUCTS,PRODS,DEC)$SUBS(PRODUCTS,PRODS))
   ))

* TERMINAL VALUE OF FORESTED LANDS

 + (SUM((PRODS)$(yesfor gt 0 and
    SUM((REGS,CLS,OWNER,SPECIES,SITE,MIC,COHORT2),
         INVENT(REGS,CLS,OWNER,SPECIES,SITE,MIC,COHORT2)) GT 0)
  ,((SUM(DEC$(ORD(DEC) EQ CARD(DEC) AND
        ABS( FPDEMAND(PRODS,DEC,"SLOPE")) GT 0.000000011),
        (( -FPDEMAND(PRODS,DEC,"INTERCEPT")/
          FPDEMAND(PRODS,DEC,"SLOPE") + 0.5/
          FPDEMAND(PRODS,DEC,"SLOPE")*
         (SCFOR*TERMVOLN(PRODS)))*
         (SCFOR*TERMVOLN(PRODS)))$(SEPFOR EQ 0)
       + (SUM(STEPS,( -FPDEMAND(PRODS,DEC,"INTERCEPT")/
          FPDEMAND(PRODS,DEC,"SLOPE") + 0.5/
          FPDEMAND(PRODS,DEC,"SLOPE")*
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         (TERMVOLQ(PRODS)*QINC(STEPS)))*
         (TERMVOLQ(PRODS)*QINC(STEPS))
             *TERMVOLNS(PRODS,STEPS)))$(SEPFOR GT 0)           ))
*  RETAIN FIXED PRICE TERMINAL CONDITION WHEN YOU DONT HAVE SLOPE
      +(TERMVOLN(PRODS)*SCFOR*TERMVALUE(PRODS))
      $ SUM(DEC$(ORD(DEC) EQ CARD(DEC)),
            1$(FPDEMAND(PRODS,DEC,"SLOPE") EQ 0)))
   *(1+DISCRATE)**(-(SUM(DEC$(ORD(DEC) EQ CARD(DEC)) ,DATE(DEC)+10-TODAY))))
   /((1+DISCRATE)**10-1))
    $YESFOR

* DEDUCT COSTS OF MANAGEMENT AND HARVESTING FOR TERMINAL INVENTORY
   -((SUM((REGS, CLS,MIC,SPECIES)$rotation(regs)
           ,ESTCOST(REGS,CLS,MIC,SPECIES)*
     (
* the following code replaces TERMAREA(REGS,CLS,MIC,SPECIES)
 +SUM(WHEN$(TODAY+ELAPSED(WHEN) GT LASTDAY),
    SUM((OWNER,PRODS,SITE,COHORT)$
        ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
         EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)))
 + SUM(OLDDEC,
      SUM((WHEN,TIME2)$(WHENDONE(OLDDEC,WHEN) GT 0 AND
  ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY EQ 10*(ORD(TIME2)-1))
   OR ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY GT 10*(ORD(TIME2)-1))
   AND (ORD(TIME2) EQ CARD(TIME2))))),
           SUM((OWNER,PRODS,SITE,POLICY)$
               (ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) GT 0
            AND examine(policy)*POLICYINC(POLICY,OLDDEC,"EXIST") gt 0 and
                YESPOLICY(POLICY,CLS,OWNER,SPECIES,SITE,MIC) GT 0),
               NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,POLICY) ))))
/(ROTATION(REGS)/10))
   +SUM((REGS,CLS,MIC,SPECIES)$rotation(regs)
           , (ROTATION(REGS)/10-1)*(
 +SUM(WHEN$(TODAY+ELAPSED(WHEN) GT LASTDAY),
    SUM((OWNER,PRODS,SITE,COHORT)$
        ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
         EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)))
 + SUM(OLDDEC,
      SUM((WHEN,TIME2)$(WHENDONE(OLDDEC,WHEN) GT 0 AND
  ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY EQ 10*(ORD(TIME2)-1))
   OR ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY GT 10*(ORD(TIME2)-1))
   AND (ORD(TIME2) EQ CARD(TIME2))))),
           SUM((OWNER,PRODS,SITE,POLICY)$
               (ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) GT 0
                   AND EXAMINE(POLICY) GT 0),
               NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,POLICY)*
               YESPOLICY(POLICY,CLS,OWNER,SPECIES,SITE,MIC)
              *POLICYINC(POLICY,OLDDEC,"EXIST")))))
       /(ROTATION(REGS)/10)*GROWCOST(REGS,CLS,MIC,SPECIES))
   +SUM((REGS,PRODS),
*the following code replaces  TERMVOL(REGS,PRODS)
   (2.0/(ROTATION(REGS)/10))*(
  +  SUM(WHEN$(TODAY+ELAPSED(WHEN) GT LASTDAY),
       SUM((CLS,OWNER,SPECIES,SITE,COHORT,MIC)$
              ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
           EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)*
           EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,WHEN)))
  +  SUM(OLDDEC,
      SUM((WHEN,TIME2)$(WHENDONE(OLDDEC,WHEN) GT 0 AND
            ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY EQ 10*(ORD(TIME2)-1))
         OR ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY GT 10*(ORD(TIME2)-1))
         AND (ORD(TIME2) EQ CARD(TIME2))))),
         SUM((CLS,OWNER,SPECIES,SITE,MIC,policy)$(
              ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
                          and examine(policy) gt 0),
              NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,policy)*
              yespolicy(policy,cls,owner,species,site,mic)
             *policyinc(policy,olddec,"exist")*
              NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,TIME2))   ))
         +ENDFUELSUB(REGS)*FUELSUBDAT(PRODS)$YESITIS(REGS,"FUELHW"))
*the above code replaces   TERMVOL(REGS,PRODS)
   *HARVCOST(PRODS,REGS)))
   *(1+DISCRATE)**(-(SUM(DEC$(ORD(DEC) EQ CARD(DEC)) ,DATE(DEC)+10-TODAY)))
   /((1+DISCRATE)**10-1))
    $YESFOR

*  DEDUCT THE PRESENT VALUE OF TRANSPORT COSTS FOR SHIPMENTS
*  OF REGULATED FLOWS FROM TERMINAL INVENTORY

    -  (SUM((REGS,PRODS)$(TRANSCOST(REGS,PRODS) NE 0 AND
                        YESITIS(REGS,PRODS) GT 0 )
             ,SCFOR*TRANSCOST(REGS,PRODS)*(SUM(DEC$(ORD(DEC) EQ CARD(DEC))
             ,TCOSTINF(DEC,REGS)))
*the following code replaces  TERMVOL(REGS,PRODS)
  *(2.0/(ROTATION(REGS)/10))*(
  +  SUM(WHEN$(TODAY+ELAPSED(WHEN) GT LASTDAY),
       SUM((CLS,OWNER,SPECIES,SITE,COHORT,MIC)$
              ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
           EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)*
           EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,WHEN)))
  +  SUM(OLDDEC,
      SUM((WHEN,TIME2)$(WHENDONE(OLDDEC,WHEN) GT 0 AND
            ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY EQ 10*(ORD(TIME2)-1))
         OR ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY GT 10*(ORD(TIME2)-1))
         AND (ORD(TIME2) EQ CARD(TIME2))))),
         SUM((CLS,OWNER,SPECIES,SITE,MIC,policy)$(
              ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
                          and examine(policy) gt 0),
              NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,policy)*
              yespolicy(policy,cls,owner,species,site,mic)
             *policyinc(policy,olddec,"exist")*
              NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,TIME2))   ))
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         +ENDFUELSUB(REGS)*FUELSUBDAT(PRODS)$YESITIS(REGS,"FUELHW")))
*the above code replaces   TERMVOL(REGS,PRODS)
   *(1+DISCRATE)**(-(SUM(DEC$(ORD(DEC) EQ CARD(DEC)) ,DATE(DEC)+10-TODAY)))
   /((1+DISCRATE)**10-1))$YESFOR
*///////////////////////////////////////////////////////////////////////////

*INTERSECTORAL LAND MOVEMENT
- SUM(DEC, DISC(DEC)*SUM((REGS,CLS,THREE)$
     sum((owner,site,spec),whentran(regs,cls,site,owner,spec,"toag"))
                    ,LANDTOAG(REGS,CLS,DEC,THREE)
             *SUM(LNDMATfrfr(LANDTYPE,CLS),SCALE(LANDTYPE)/SCFOR)
             *scfor *CONVERT(REGS,CLS,"CCOST",THREE)$
          YESCONLND(REGS,CLS,three)))$( YESFOR*YESAG GT 0)

*AGRICULTURAL PART OF OBJECTIVE FUNCTION
  + (SUM(DEC,DISC(DEC)*WTAG(DEC)*
* DOMESTIC PRIMARY DEMAND
      ( SUM(PRIMARY$(PDEMAND(PRIMARY,"QUANTITY")   GT 0 AND
             PDEMAND(PRIMARY,"PRICE")      GT 0 AND
             PDEMAND(PRIMARY,"ELASTICITY") LT -0.05     ),
          ((DEMANDP(DEC,PRIMARY)*SCALE(PRIMARY)/
           (PDEMAND(PRIMARY,"QUANTITY")*DEMANDGRW(PRIMARY,DEC)))
                      **(1./PDEMAND(PRIMARY,"ELASTICITY"))
          * DEMANDP(DEC,PRIMARY)*SCALE(PRIMARY)* PDEMAND(PRIMARY,"PRICE")
          * PDEMAND(PRIMARY,"ELASTICITY")/(1.+PDEMAND(PRIMARY,"ELASTICITY"))
         - (1.0/PDEMAND(PRIMARY,"TFAC")) **(1.0/PDEMAND(PRIMARY,"ELASTICITY"))
           *PDEMAND(PRIMARY,"QUANTITY")/PDEMAND(PRIMARY,"TFAC")
           *DEMANDGRW(PRIMARY,DEC) *PDEMAND(PRIMARY,"PRICE")
          /(1.0+(1.0/PDEMAND(PRIMARY,"ELASTICITY")))
         +(1.0/PDEMAND(PRIMARY,"TFAC"))
              **(1.0+1.0/PDEMAND(PRIMARY,"ELASTICITY"))
          *PDEMAND(PRIMARY,"QUANTITY")*DEMANDGRW(PRIMARY,DEC)
          *PDEMAND(PRIMARY,"PRICE") )      $(SEPAG LE 0)
      +(SUM(STEPS$(PDEMAND(PRIMARY,"TFAC") GE 1/QINC(STEPS)
               AND PDEMAND(PRIMARY,"TFAC") GE QINC(STEPS)),
           (QINC(STEPS)**(1./PDEMAND(PRIMARY,"ELASTICITY"))
          * PDEMAND(PRIMARY,"QUANTITY")*QINC(STEPS)*DEMANDGRW(PRIMARY,DEC)
          * PDEMAND(PRIMARY,"PRICE")
          * PDEMAND(PRIMARY,"ELASTICITY")/(1.+PDEMAND(PRIMARY,"ELASTICITY"))
         - (1.0/PDEMAND(PRIMARY,"TFAC")**(1.0/PDEMAND(PRIMARY,"ELASTICITY"))
           * PDEMAND(PRIMARY,"QUANTITY")/PDEMAND(PRIMARY,"TFAC")
           * DEMANDGRW(PRIMARY,DEC)     *PDEMAND(PRIMARY,"PRICE")
           *PDEMAND(PRIMARY,"ELASTICITY")/(1.0+PDEMAND(PRIMARY,"ELASTICITY")))
       +(1.0/PDEMAND(PRIMARY,"TFAC"))**(1.0+1.0/PDEMAND(PRIMARY,"ELASTICITY"))
         *PDEMAND(PRIMARY,"QUANTITY")*DEMANDGRW(PRIMARY,DEC)
         *PDEMAND(PRIMARY,"PRICE") )*DEMANDPS(DEC,PRIMARY,STEPS)))$SEPAG)
      + SUM(PRIMARY$(PDEMAND(PRIMARY,"PRICE")      GT 0 AND
            PDEMAND(PRIMARY,"ELASTICITY") GE -0.05
            AND PDEMAND(PRIMARY,"QUANTITY") NE 0   ),
            PDEMAND(PRIMARY,"PRICE")*DEMANDP(DEC,PRIMARY)*SCALE(PRIMARY))
* EXPORT PRIMARY DEMAND
     +( SUM(PRIMARY$(PEXPORT(PRIMARY,"QUANTITY")   GT 0 AND
             PEXPORT(PRIMARY,"PRICE")      GT 0 AND
             PEXPORT(PRIMARY,"ELASTICITY") LT -0.05     ),
          ((EXPORTP(DEC,PRIMARY)*SCALE(PRIMARY)/
           (PEXPORT(PRIMARY,"QUANTITY")*EXPORTGRW(PRIMARY,DEC)))
                         **(1./PEXPORT(PRIMARY,"ELASTICITY"))
          * EXPORTP(DEC,PRIMARY)*SCALE(PRIMARY)* PEXPORT(PRIMARY,"PRICE")
          * PEXPORT(PRIMARY,"ELASTICITY")/(1.+PEXPORT(PRIMARY,"ELASTICITY"))
         - (1.0/PEXPORT(PRIMARY,"TFAC"))**(1.0/PEXPORT(PRIMARY,"ELASTICITY"))
           *PEXPORT(PRIMARY,"QUANTITY")/PEXPORT(PRIMARY,"TFAC")
           *EXPORTGRW(PRIMARY,DEC)     *PEXPORT(PRIMARY,"PRICE")
           /(1.0+(1.0/PEXPORT(PRIMARY,"ELASTICITY")))
       +(1.0/PEXPORT(PRIMARY,"TFAC"))**(1.0+1.0/PEXPORT(PRIMARY,"ELASTICITY"))
           *PEXPORT(PRIMARY,"QUANTITY")*exportGRW(PRIMARY,DEC)
           *PEXPORT(PRIMARY,"PRICE"))     $(SEPAG LE 0)
     + (SUM(STEPS$(PEXPORT(PRIMARY,"TFAC") GE 1/QINC(STEPS)
               AND PEXPORT(PRIMARY,"TFAC") GE QINC(STEPS)),
           (QINC(STEPS)**(1./PEXPORT(PRIMARY,"ELASTICITY"))
          * PEXPORT(PRIMARY,"QUANTITY")*QINC(STEPS)*EXPORTGRW(PRIMARY,DEC)
          * PEXPORT(PRIMARY,"PRICE")
          * PEXPORT(PRIMARY,"ELASTICITY")/(1.+PEXPORT(PRIMARY,"ELASTICITY"))
        - (1.0/PEXPORT(PRIMARY,"TFAC")**(1.0/PEXPORT(PRIMARY,"ELASTICITY"))
          *PEXPORT(PRIMARY,"QUANTITY")/PEXPORT(PRIMARY,"TFAC")
          *EXPORTGRW(PRIMARY,DEC)     *PEXPORT(PRIMARY,"PRICE")
          *PEXPORT(PRIMARY,"ELASTICITY")/(1.0+PEXPORT(PRIMARY,"ELASTICITY")))
        +(1.0/PEXPORT(PRIMARY,"TFAC"))**(1.0+1.0/PEXPORT(PRIMARY,"ELASTICITY"))
          *PEXPORT(PRIMARY,"QUANTITY")*exportGRW(PRIMARY,DEC)
          *PEXPORT(PRIMARY,"PRICE"))*
          EXPORTPS(DEC,PRIMARY,STEPS)    ) )   $SEPAG    ))
     + SUM(PRIMARY$(PEXPORT(PRIMARY,"PRICE")      GT 0 AND
           PEXPORT(PRIMARY,"ELASTICITY") GE -0.05
           AND PEXPORT(PRIMARY,"QUANTITY") NE 0    ),
          PEXPORT(PRIMARY,"PRICE")*EXPORTP(DEC,PRIMARY)*SCALE(PRIMARY))
* PRIMARY IMPORT SUPPLY
    - SUM(PRIMARY$(PIMPORT(PRIMARY,"PRICE")      GT 0 AND
              PIMPORT(PRIMARY,"QUANTITY")   GT 0 AND
              PIMPORT(PRIMARY,"ELASTICITY") GT 0.05     ),
           (PIMPORT(PRIMARY,"ELASTICITY")/(1.+PIMPORT(PRIMARY,"ELASTICITY"))
         * (PIMPORT(PRIMARY,"PRICE")  *(IMPORTP(DEC,PRIMARY)*SCALE(PRIMARY)
         / (PIMPORT(PRIMARY,"QUANTITY")*IMPORTGRW(PRIMARY,DEC)))
                  **(1./PIMPORT(PRIMARY,"ELASTICITY"))
         * IMPORTP(DEC,PRIMARY)*SCALE(PRIMARY)))
            $(SEPAG LE 0 OR PIMPORT(PRIMARY,"ELASTICITY") LE 0.05)
    +( SUM(STEPS,
            PIMPORT(PRIMARY,"ELASTICITY")/(1.+PIMPORT(PRIMARY,"ELASTICITY"))
         * (PIMPORT(PRIMARY,"PRICE")
         *  QINC(STEPS)**(1./PIMPORT(PRIMARY,"ELASTICITY"))
         *  (PIMPORT(PRIMARY,"QUANTITY")*IMPORTGRW(PRIMARY,DEC))*QINC(STEPS)
         *  IMPORTPS(DEC,PRIMARY,STEPS))))
               $(SEPAG GT 0 AND PIMPORT(PRIMARY,"ELASTICITY") GT 0.05))
         - SUM(PRIMARY$(PIMPORT(PRIMARY,"PRICE")      GT 0 AND
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                        PIMPORT(PRIMARY,"ELASTICITY") LE 0.05
                    AND PIMPORT(PRIMARY,"QUANTITY") NE 0       ),
               PIMPORT(PRIMARY,"PRICE")*IMPORTP(DEC,PRIMARY)*SCALE(PRIMARY))
* SECONDARY DOMESTIC DEMAND
    + ( SUM(SECONDARY$(SDEMAND(SECONDARY,"QUANTITY")   GT 0 AND
             SDEMAND(SECONDARY,"PRICE")      GT 0 AND
             SDEMAND(SECONDARY,"ELASTICITY") LT -0.05     ),
           ((DEMANDS(DEC,SECONDARY)*SCALE(SECONDARY)/
            (SDEMAND(SECONDARY,"QUANTITY")*DEMANDGRW(SECONDARY,DEC)))
                      **(1./SDEMAND(SECONDARY,"ELASTICITY"))
           * DEMANDS(DEC,SECONDARY)*SCALE(SECONDARY)
           * SDEMAND(SECONDARY,"PRICE")
           * SDEMAND(SECONDARY,"ELASTICITY")
           / (1.+SDEMAND(SECONDARY,"ELASTICITY"))
         - (1.0/SDEMAND(SECONDARY,"TFAC"))
                   **(1.0/SDEMAND(SECONDARY,"ELASTICITY"))
           * SDEMAND(SECONDARY,"QUANTITY")/SDEMAND(SECONDARY,"TFAC")
           * DEMANDGRW(SECONDARY,DEC) *SDEMAND(SECONDARY,"PRICE")
           / (1.0+(1.0/SDEMAND(SECONDARY,"ELASTICITY")))
         +  (1.0/SDEMAND(SECONDARY,"TFAC"))
                  **(1.0+1.0/SDEMAND(SECONDARY,"ELASTICITY"))
           * SDEMAND(SECONDARY,"QUANTITY")*DEMANDGRW(SECONDARY,DEC)
           * SDEMAND(SECONDARY,"PRICE") )     $(SEPAG LE 0)
     + (SUM(STEPS$(SDEMAND(SECONDARY,"TFAC") GE 1/QINC(STEPS)
                 AND SDEMAND(SECONDARY,"TFAC") GE QINC(STEPS)),
           (QINC(STEPS)**(1./SDEMAND(SECONDARY,"ELASTICITY"))
       * SDEMAND(SECONDARY,"QUANTITY")*QINC(STEPS)*DEMANDGRW(SECONDARY,DEC)
       * SDEMAND(SECONDARY,"PRICE")
       * SDEMAND(SECONDARY,"ELASTICITY")/(1.+SDEMAND(SECONDARY,"ELASTICITY"))
     -   (1.0/SDEMAND(SECONDARY,"TFAC")**(1.0/SDEMAND(SECONDARY,"ELASTICITY"))
       * SDEMAND(SECONDARY,"QUANTITY")/SDEMAND(SECONDARY,"TFAC")
       * DEMANDGRW(SECONDARY,DEC)     *SDEMAND(SECONDARY,"PRICE")
       *SDEMAND(SECONDARY,"ELASTICITY")/(1.0+SDEMAND(SECONDARY,"ELASTICITY")))
     +  (1.0/SDEMAND(SECONDARY,"TFAC"))
              **(1.0+1.0/SDEMAND(SECONDARY,"ELASTICITY"))
       * SDEMAND(SECONDARY,"QUANTITY")*DEMANDGRW(SECONDARY,DEC)
       * SDEMAND(SECONDARY,"PRICE"))
       * DEMANDSS(DEC,SECONDARY,STEPS)    ) )   $SEPAG    ))
    +SUM(SECONDARY$(SDEMAND(SECONDARY,"PRICE")      GT 0 AND
                    SDEMAND(SECONDARY,"ELASTICITY") GE -0.05
                AND SDEMAND(SECONDARY,"QUANTITY") NE 0    ),
           SDEMAND(SECONDARY,"PRICE")*DEMANDS(DEC,SECONDARY)*SCALE(SECONDARY))
* SECONDARY EXPORT DEMAND
   +( SUM(SECONDARY$(SEXPORT(SECONDARY,"QUANTITY")   GT 0 AND
                     SEXPORT(SECONDARY,"PRICE")      GT 0 AND
                     SEXPORT(SECONDARY,"ELASTICITY") LT -0.05     ),
         ((EXPORTS(DEC,SECONDARY)*SCALE(SECONDARY)/
          (SEXPORT(SECONDARY,"QUANTITY")*EXPORTGRW(SECONDARY,DEC)))
                      **(1./SEXPORT(SECONDARY,"ELASTICITY"))
        * EXPORTS(DEC,SECONDARY)*SCALE(SECONDARY)* SEXPORT(SECONDARY,"PRICE")
        * SEXPORT(SECONDARY,"ELASTICITY")/(1.+SEXPORT(SECONDARY,"ELASTICITY"))
     -  (1.0/SEXPORT(SECONDARY,"TFAC"))**(1.0/SEXPORT(SECONDARY,"ELASTICITY"))
        * SEXPORT(SECONDARY,"QUANTITY")/SEXPORT(SECONDARY,"TFAC")
        * EXPORTGRW(SECONDARY,DEC)     *SEXPORT(SECONDARY,"PRICE")
        / (1.0+(1.0/SEXPORT(SECONDARY,"ELASTICITY")))
     +  (1.0/SEXPORT(SECONDARY,"TFAC"))
                 **(1.0+1.0/SEXPORT(SECONDARY,"ELASTICITY"))
       * SEXPORT(SECONDARY,"QUANTITY")*exportGRW(SECONDARY,DEC)
       * SEXPORT(SECONDARY,"PRICE"))     $(SEPAG LE 0)
   + (SUM(STEPS$(SEXPORT(SECONDARY,"TFAC") GE 1/QINC(STEPS) AND
                 SEXPORT(SECONDARY,"TFAC") GE QINC(STEPS)),
        (QINC(STEPS)**(1./SEXPORT(SECONDARY,"ELASTICITY"))
      * SEXPORT(SECONDARY,"QUANTITY")*QINC(STEPS)*EXPORTGRW(SECONDARY,DEC)
      * SEXPORT(SECONDARY,"PRICE")
      * SEXPORT(SECONDARY,"ELASTICITY")/(1.+SEXPORT(SECONDARY,"ELASTICITY"))
     -  (1.0/SEXPORT(SECONDARY,"TFAC")**(1.0/SEXPORT(SECONDARY,"ELASTICITY"))
      * SEXPORT(SECONDARY,"QUANTITY")/SEXPORT(SECONDARY,"TFAC")
      * EXPORTGRW(SECONDARY,DEC)     *SEXPORT(SECONDARY,"PRICE")
      * SEXPORT(SECONDARY,"ELASTICITY")/(1.0+SEXPORT(SECONDARY,"ELASTICITY")))
    + (1.0/SEXPORT(SECONDARY,"TFAC"))
            **(1.0+1.0/SEXPORT(SECONDARY,"ELASTICITY"))
      * SEXPORT(SECONDARY,"QUANTITY")*exportGRW(SECONDARY,DEC)
      * SEXPORT(SECONDARY,"PRICE"))* EXPORTSS(DEC,SECONDARY,STEPS))) $SEPAG ))
   +  SUM(SECONDARY$(SEXPORT(SECONDARY,"PRICE")      GT 0 AND
               SEXPORT(SECONDARY,"ELASTICITY") GE -0.05
              AND SEXPORT(SECONDARY,"QUANTITY") NE 0    ),
        SEXPORT(SECONDARY,"PRICE")*EXPORTS(DEC,SECONDARY) *SCALE(SECONDARY))
* SECONDARY imPORT supply
   - SUM(SECONDARY$(SIMPORT(SECONDARY,"QUANTITY")   GT 0 AND
                    SIMPORT(SECONDARY,"PRICE")      GT 0 AND
                    SIMPORT(SECONDARY,"ELASTICITY") GT 0.05        ),
         (SIMPORT(SECONDARY,"ELASTICITY")/(1.+SIMPORT(SECONDARY,"ELASTICITY"))
       * (SIMPORT(SECONDARY,"PRICE")*(IMPORTS(DEC,SECONDARY)*SCALE(SECONDARY)
       / (SIMPORT(SECONDARY,"QUANTITY")*IMPORTGRW(SECONDARY,DEC)))**
                   (1./SIMPORT(SECONDARY,"ELASTICITY"))
       * IMPORTS(DEC,SECONDARY)*SCALE(SECONDARY)))
            $(SEPAG LE 0 OR SIMPORT(SECONDARY,"ELASTICITY") LE 0.05)
     + (SUM(STEPS,SIMPORT(SECONDARY,"ELASTICITY")
       / (1.+SIMPORT(SECONDARY,"ELASTICITY"))*(SIMPORT(SECONDARY,"PRICE")
       * QINC(STEPS)**(1./SIMPORT(SECONDARY,"ELASTICITY"))
       * (SIMPORT(SECONDARY,"QUANTITY")*IMPORTGRW(SECONDARY,DEC))*QINC(STEPS)
       * IMPORTSS(DEC,SECONDARY,STEPS))))
          $(SEPAG GT 0 AND SIMPORT(SECONDARY,"ELASTICITY") GT 0.05))
   - SUM(SECONDARY$(SIMPORT(SECONDARY,"PRICE")      GT 0 AND
                    SIMPORT(SECONDARY,"ELASTICITY") LE 0.05
                AND SIMPORT(SECONDARY,"QUANTITY") NE 0     ),
         SIMPORT(SECONDARY,"PRICE")*IMPORTS(DEC,SECONDARY)*SCALE(SECONDARY))
*LAND SUPPLY
   - SUM((REGS,LANDTYPE)$(NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY") GT 0 AND
                          NEWLNDSUPP(LANDTYPE,REGS,"PRICE")    GT 0 AND
                          NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") GT 0.05  ),
            ((NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY")
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          / (1.+NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY"))
          * NEWLNDSUPP(LANDTYPE,REGS,"PRICE")
          * (LANDSUPPLY(DEC,REGS,LANDTYPE)*SCALE(LANDTYPE)
          / (NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY")
          * AGLANDGRW(REGS,LANDTYPE,DEC)))
               **(1./NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY")))
          * LANDSUPPLY(DEC,REGS,LANDTYPE)*SCALE(LANDTYPE))$(SEPAG EQ 0)
       + SUM(STEPS,(NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY")
          / (1.+NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY"))
          * NEWLNDSUPP(LANDTYPE,REGS,"PRICE")
          * QINC(STEPS)**(1./NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY"))
          * NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY")*AGLANDGRW(REGS,LANDTYPE,DEC)
          * QINC(STEPS))
          * LANDSUPPLS(DEC,REGS,LANDTYPE,STEPS) )$(SEPAG GT 0))
   - SUM((REGS,LANDTYPE)$(NEWLNDSUPP(LANDTYPE,REGS,"PRICE") GT 0 AND
                          NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") LE 0.05 AND
                          NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY") NE 0.0  ),
            NEWLNDSUPP(LANDTYPE,REGS,"PRICE")
          * LANDSUPPLY(DEC,REGS,LANDTYPE)*SCALE(LANDTYPE))
*WATER SUPPLY
   - SUM(REGS$(     NEWWATSUP(REGS,"PUMPQ")      GT 0 AND
                    NEWWATSUP(REGS,"PUMPPRICE")  GT 0 AND
                    NEWWATSUP(REGS,"PUMPELAS")   GT 0.05   ),
          (NEWWATSUP(REGS,"PUMPELAS") /(1.+NEWWATSUP(REGS,"PUMPELAS"))
        * NEWWATSUP(REGS,"PUMPPRICE")* (WATERVAR(DEC,REGS)*SCALE("WATER")
        / (NEWWATSUP(REGS,"PUMPQ")*WATERGRW(REGS,DEC)))
             **(1./NEWWATSUP(REGS,"PUMPELAS"))
        * WATERVAR(DEC,REGS)*SCALE("WATER"))$(SEPAG LE 0)
   + SUM(STEPS,  NEWWATSUP(REGS,"PUMPELAS") /(1.+NEWWATSUP(REGS,"PUMPELAS"))
        * NEWWATSUP(REGS,"PUMPPRICE")*(QINC(STEPS))
              **(1./NEWWATSUP(REGS,"PUMPELAS"))
        * (NEWWATSUP(REGS,"PUMPQ")*WATERGRW(REGS,DEC)*QINC(STEPS))
        * WATERVARS(DEC,REGS,STEPS))$(SEPAG GT 0))
   - SUM(REGS$(NEWWATSUP(REGS,"PUMPPRICE")  GT 0 AND
               NEWWATSUP(REGS,"PUMPELAS")   LE 0.05 AND
               NEWWATSUP(REGS,"PUMPQ") NE 0.0     ),
         NEWWATSUP(REGS,"PUMPPRICE")*WATERVAR(DEC,REGS)*SCALE("WATER"))
   - SUM(REGS,WATERFIX(DEC,REGS)* NEWWATSUP(REGS,"FIXEDPRC")*SCALE("WATER"))
*AUMS SUPPLY
   - SUM(REG$( NEWAUMSSUP(REG,"PRIVATEQ")      GT 0 AND
               NEWAUMSSUP(REG,"PRIVATEP")      GT 0 AND
               NEWAUMSSUP(REG,"PRIVATELAS")    GT 0.05   ),
          (NEWAUMSSUP(REG,"PRIVATELAS") /(1.+NEWAUMSSUP(REG,"PRIVATELAS"))
        * NEWAUMSSUP(REG,"PRIVATEP")
        * (AUMSPRIV(DEC,REG)*SCALE("AUMS")/NEWAUMSSUP(REG,"PRIVATEQ"))
                    **(1./NEWAUMSSUP(REG,"PRIVATELAS"))
        * AUMSPRIV(DEC,REG)*SCALE("AUMS")) $(SEPAG LE 0)
   + SUM(STEPS,NEWAUMSSUP(REG,"PRIVATELAS") /(1.+NEWAUMSSUP(REG,"PRIVATELAS"))
        * NEWAUMSSUP(REG,"PRIVATEP")*(QINC(STEPS))
               **(1./NEWAUMSSUP(REG,"PRIVATELAS"))
        * NEWAUMSSUP(REG,"PRIVATEQ")*QINC(STEPS)*AUMSPRIVS(DEC,REG,STEPS))
           $(SEPAG GT 0)   )
   - SUM(REG$(NEWAUMSSUP(REG,"PRIVATEP")  GT 0 AND
               NEWAUMSSUP(REG,"PRIVATELAS")   LE 0.05 AND
               NEWAUMSSUP(REG,"PRIVATEQ") NE 0.0     ),
         NEWAUMSSUP(REG,"PRIVATEP")* AUMSPRIV(DEC,REG)*SCALE("AUMS"))
   - SUM(REG$NEWAUMSSUP(REG,"PUBLICPRC"),AUMSPUB(DEC,REG)
         * NEWAUMSSUP(REG,"PUBLICPRC")*SCALE("AUMS"))
*LABOR SUPPLY
   - SUM(REGS$(NEWLABSUPP(REGS,"HIREQ")      GT 0 AND
               NEWLABSUPP(REGS,"HIREP")      GT 0 AND
               NEWLABSUPP(REGS,"HIREELAS")   GT 0.05     ),
           (NEWLABSUPP(REGS,"HIREELAS") /(1.+NEWLABSUPP(REGS,"HIREELAS"))
         * NEWLABSUPP(REGS,"HIREP")*(HIRED(DEC,REGS)*SCALE("LABOR")/
           (NEWLABSUPP(REGS,"HIREQ")*LABORGRW(REGS,DEC)))**
                       (1./NEWLABSUPP(REGS,"HIREELAS"))
         * HIRED(DEC,REGS)*SCALE("LABOR") ) $(SEPAG LE 0)
      + SUM(STEPS,
           (NEWLABSUPP(REGS,"HIREELAS") /(1.+NEWLABSUPP(REGS,"HIREELAS"))
         * NEWLABSUPP(REGS,"HIREP")*(QINC(STEPS))
                  **(1./NEWLABSUPP(REGS,"HIREELAS"))
         * NEWLABSUPP(REGS,"HIREQ")*LABORGRW(REGS,DEC)*QINC(STEPS)
         * HIREDS(DEC,REGS,STEPS) ))$SEPAG)
    - SUM(REGS$(NEWLABSUPP(REGS,"HIREQ")    LE 0 AND
                NEWLABSUPP(REGS,"HIREP")    GT 0 AND
                NEWLABSUPP(REGS,"HIREELAS") LE 0.05 AND
                NEWLABSUPP(REGS,"HIREQ") NE 0.0),
          NEWLABSUPP(REGS,"HIREP")*HIRED(DEC,REGS)*SCALE("LABOR"))
    - SUM(REGS,FAMILY(DEC,REGS)* NEWLABSUPP(REGS,"FAMILYPRC")*SCALE("LABOR"))
*CROP PRODUCTION COSTS
    - SUM((REGS,CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) GT 0.0 AND
               NEWBUDDATA(CROP,REGS,CROP,WTECH,"PARTICIP",TECH) GT 0.0),
           ( TUNE(CROP)
           + SUM(COST,NEWBUDDATA(COST,REGS,CROP,WTECH,"PARTICIP",TECH)
                   * AGQDYN(COST,DEC)))
                   * cropBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)*SCALPROD
           + (TUNE(CROP)
           + SUM(COST,NEWBUDDATA(COST,REGS,CROP,WTECH,"NONPART",TECH)
                  * AGQDYN(COST,DEC)))
                  * CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)*SCALPROD)
    - SUM((REGS,CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0 AND
                         NEWBUDDATA(CROP,REGS,CROP,WTECH,"BASE",TECH) GT 0.0),
           + (TUNE(CROP)
           + SUM(COST,NEWBUDDATA(COST,REGS,CROP,WTECH,"BASE",TECH)
                  * AGQDYN(COST,DEC)))
                  * CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)*SCALPROD  )
*LIVESTOCK PRODUCTION COSTS
    - SUM((REGS,ANIMAL,LIVETECH),
         (SUM(COST,NEWLIVEBUD(COST,REGS,ANIMAL,LIVETECH)*AGQDYN(COST,DEC)))
                 * LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH) )*SCALLIVE
*PROCESSING COSTS
    - SUM(PROCESSALT,PROCESS(DEC,PROCESSALT)*SCALPROC*
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           (SUM(COST,PROCBUD(COST,PROCESSALT)*AGQDYN(COST,DEC)))   )
*NATIONAL INPUT COSTS
   - SUM(INPUT,INPUTPRICE(INPUT)*DYNINPCOST(INPUT,DEC)*(
        +SUM(REGS,
             SUM((CROP,WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
                  CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
                   * SCALPROD * AGQDYN(INPUT,DEC)
                   * NEWBUDDATA(INPUT,REGS,CROP,WTECH,"PARTICIP",TECH)
                + CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
                   * SCALPROD * AGQDYN(INPUT,DEC)
                   * NEWBUDDATA(INPUT,REGS,CROP,WTECH,"NONPART",TECH) )
           + SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                   CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                    * SCALPROD*AGQDYN(INPUT,DEC)
                    * NEWBUDDATA(INPUT,REGS,CROP,WTECH,"BASE",TECH) )
           + SUM((ANIMAL,LIVETECH),
                LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)*AGQDYN(INPUT,DEC)
               *SCALLIVE*NEWLIVEBUD(INPUT,REGS,ANIMAL,LIVETECH)))
           + SUM(PROCESSALT,PROCESS(DEC,PROCESSALT)*PROCBUD(INPUT,PROCESSALT)
                 *AGQDYN(INPUT,DEC))*SCALPROC))
*FARM PROGRAM PARTICIPATION REVENUES
   + SUM(CROP$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND
               FARMPROD("SLIPPAGE",CROP) GT 0 AND
               FARMPROD("MKTLOANY-N",CROP) GT 0),
       (FARMPROD("DEFIC",CROP)
     +  FARMPROD("MKTLOANY-N",CROP)*FARMPROD("MKTLOAN",CROP))
       *DEFPRODN(DEC,CROP) *SCALE(CROP)*FARMPROGY(DEC)    )
   + SUM(CROP$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND
            FARMPROD("SLIPPAGE",CROP) GT 0 AND
            FARMPROD("MKTLOANY-N",CROP) LE 0),
       (FARMPROD("DEFIC",CROP)*DEFPRODN(DEC,CROP)*SCALE(CROP)*FARMPROGY(DEC)))
   + SUM(CROP$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0),
        FARMPROD("DEFIC",CROP)*PRDN5092(DEC,CROP) *SCALE(CROP))
   + SUM(CROP$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 ),
        FARMPROD("DIVERPAY",CROP)*DIVPRODN(DEC,CROP) *SCALE(CROP) )
   + SUM(CROP$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC)  GT 0 AND
               FARMPROD("FPYIELD",CROP) GT 1.0),
        FARMPROD("DEFIC",CROP)*ARTIF(DEC,CROP) *SCALE(CROP)   )
   + SUM(CROP$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND
               FARMPROD("UNHARVACR",CROP) GT 0),
        FARMPROD("DEFIC",CROP)*UNHARV(DEC,CROP)  *SCALE(CROP)  )
   + SUM(PRIMARY$(FARMPROD("LOANRATE",PRIMARY)*FARMPROGY(DEC) GT 0 AND
               FARMPROD("MKTLOANY-N",PRIMARY) LT 1.0 AND FARMPROGY(DEC) GT 0),
        FARMPROD("LOANRATE",PRIMARY)*CCCLOANP(DEC,PRIMARY)*SCALE(PRIMARY) )
   + SUM(SECONDARY$(FARMPROD("LOANRATE",SECONDARY)*FARMPROGY(DEC) GT 0 AND
                FARMPROD("MKTLOANY-N",SECONDARY) LT 1.0
                AND FARMPROGY(DEC) GT 0),
        FARMPROD("LOANRATE",SECONDARY)*CCCLOANS(DEC,SECONDARY)
                 *SCALE(SECONDARY)))
        /SCALOBJ ))$(YESAG GT 0) ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   EXISTING FORESTED LAND AVAILABLE EQUATION

   THIS EQUATION IS DEFINED FOR A REGION,TYPE OF LAND,TYPE OF OWNERER,
       COHORT OF TREES, SITE CLASS, MIC, AND LAND SUITABILITY CLASS
   THE EQUATION LIMITS THE USE OF THE ACREAGE TO THE LAND AVAILABLE
   THE $ NOTATION AFTER THE INVENTORYA LINE CAUSES THE CONSTRAINT TO ONLY
         EXIST WHEN THERE ARE INVENTORY DATA
   THE $ NOTATION AFTER THE MI SUM IN THE EXIST TERM LIMITS
      THE MANAGEMENT ALTERNATIVES CONSIDERED TO ACTIVITIES WHICH HAVE YIELDS

$OFFTEXT

INVENTORYA(REGS,CLS,OWNER,SPECIES,SITE,MIC,COHORT)
        $(INVENT(REGS,CLS,OWNER,SPECIES,SITE,MIC,COHORT) GT 0
          AND YESFOR GT 0)..

     SUM(WHEN$ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
         EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN))
   =E=
    INVENT(REGS,CLS,OWNER,SPECIES,SITE,MIC,COHORT)/SCFOR;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   BALANCE EQUATION FOR LAND WHICH CAN BE REFORESTED

   THIS EQUATION IS DEFINED FOR A REGION, CLS, TYPE OF OWNERER,
       SITE, AND DEC

*   THIS EQUATION BALANCES LAND HARVESTED THIS DEC PLUS PRIOR IDLED
*       LAND AND LAND CONVERTED FROM AG WITH NEWLY PLANTED LAND,
*       LAND CONVERTED TO AG AND LAND IDLED

   THE $ NOTATION AFTER THE LANDBALANC EQUATION DEFINITION LINE
       CAUSES THE CONSTRAINT TO ONLY BE DEFINED WHEN THERE IS
       SOME OF THIS TYPE OF LAND AVAILABLE

   THE $ NOTATION AFTER THE WHEN SUM IN THE FIRST (EXIST) TERM
       LIMITS THE MANAGEMENT ALTERNATIVES CONSIDERED TO ACTIVITIES
       WHICH ARE HARVESTED IN THIS DEC

   THE $ NOTATION AFTER THE MIC SUM IN THE FIRST (EXIST) TERM
       LIMITS THE MANAGEMENT ALTERNATIVES CONSIDERED TO ACTIVITIES
       WHICH HAVE YIELDS AND THOSE WHICH LEAVE LAND IN THIS CONDITION

  THE $ NOTATION AFTER THE WHEN SUM IN THE SECOND (NEW) TERM
       LIMITS THE REESTABLISHMENT ALTERNATIVES CONSIDERED TO
       ACTIVITIES WHICH HAVE NONZERO YIELDS
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*   THE $ NOTATION IN THE IDLE TERM LIMITS IDLE LAND CONSIDERATION
*       TO DECS AFTER THE FIRST

$OFFTEXT

 LANDBALANC(REGS,CLS,OWNER,SITE,DEC,SPEC)
 $ (SUM((MIC,SPECIES,WHEN),
       ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN)) GT 0
          AND YESFOR GT 0)..

 -SUM(WHEN$(TODAY+ELAPSED(WHEN) EQ DATE(DEC)),
     SUM(SPECIES$SPMAPPR(SPECIES,SPEC),
        SUM((MIC,COHORT)$ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
           EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN))))
 + SUM(SPECIES$SPMAPFOL(SPEC,SPECIES),
      SUM((MIC,WHEN,policy)$
        (ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN)*WHENDONE(DEC,WHEN) GT 0
          and examine(policy) gt 0),
         NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DEC,policy)*
         yespolicy(policy,cls,owner,species,site,mic)
        *policyinc(policy,dec,"exist")))
 - SUM(SPMAPPR(SPECIES,SPEC),SUM((MIC,OLDDEC,WHEN,policy)
             $(DATE(OLDDEC)+ELAPSED(WHEN) EQ DATE(DEC)
                             and examine(policy) gt 0
                             AND
              (ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN)
               *WHENDONE(OLDDEC,WHEN)) GT 0),
       NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,policy)*
          yespolicy(policy,cls,owner,species,site,mic)
         *policyinc(policy,olddec,"exist")))
 + (CONVRTTOAG(REGS,CLS ,DEC,SPEC)$whentran(regs,cls,site,owner,spec,"toag")
 -  CONVRTFRAG(REGS,CLS,DEC,SPEC)$whentran(regs,cls,site,owner,spec,"fromag")
               $(YESFOR*YESAG))

 =E=
   LANDTRN(REGS,CLS,OWNER,SITE,DEC,SPEC)/SCFOR;

 sipLANDBAL(REGS,CLS,SITE,DEC,SPEC)
 $ (SUM((sipMIC,SPECIES,WHEN) $SPMAPFOL(SPEC,SPECIES),
        ISNEW(REGS,CLS,"op",SPECIES,SITE,sipmic,WHEN)) GT 0
          AND YESFOR GT 0
          and examine("sip")*policyinc("sip",dec,"exist") gt 0)..

 -SUM(WHEN$(TODAY+ELAPSED(WHEN) EQ DATE(DEC)),
     SUM(SPECIES$SPMAPPR(SPECIES,SPEC),
        SUM((COHORT)$ISEXIST(REGS,CLS,"op",SPECIES,SITE,COHORT,"lo",WHEN),
           EXIST(REGS,CLS,"op",SPECIES,SITE,COHORT,"lo",WHEN))))
 + SUM(SPECIES$SPMAPFOL(SPEC,SPECIES),
      SUM((sipMIC,WHEN)$
        (ISNEW(REGS,CLS,"op",SPECIES,SITE,sipMIC,WHEN)*WHENDONE(DEC,WHEN) GT 0),
         NEW(REGS,CLS,"op",SPECIES,SITE,sipMIC,WHEN,DEC,"sip")*
         yespolicy("sip",cls,"op",species,site,sipmic)
        *policyinc("sip",dec,"exist")))
 - SUM(SPMAPPR(SPECIES,SPEC),SUM((OLDDEC,WHEN)
             $(DATE(OLDDEC)+ELAPSED(WHEN) EQ DATE(DEC)
                             AND
              (ISNEW(REGS,CLS,"op",SPECIES,SITE,"lo",WHEN)
               *WHENDONE(OLDDEC,WHEN)) GT 0),
       NEW(REGS,CLS,"op",SPECIES,SITE,"lo",WHEN,OLDDEC,"existing")         ))
 =L=    0;

 availmoney(policy) $ ( examine(policy) gt 0 and money(policy) gt 0)..
* COST TO ESTABLISH A NEW STAND
sum((REGS,dec)$policyinc(policy,dec,"exist"),
      SUM(WHEN$(ELAPSED(WHEN) NE 0
               AND WHENDONE(DEC,WHEN) GT 0),
          SUM((CLS,OWNER,SITE,SPECIES,MIC)
              $(ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
            and yespolicy(policy,cls,owner,species,site,mic) gt 0),
             (GROWCOST(REGS,CLS,MIC,SPECIES)*4/10
             *(policyinc(policy,dec,"maintain"))
             +ESTCOST(REGS,CLS,MIC,SPECIES)
             *(policyinc(policy,dec,"establish")))
             *NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DEC,policy) ))
* COST TO MAINTAIN A NEW STAND ESTABLISHED BUT NOT YET AT HARVESTABLE AGE.
 +SUM(DECSP$(DATE(DECSP) LE DATE(DEC)
         and policyinc(policy,decsp,"exist") gt 0),
      SUM(WHEN$(DATE(DECSP)+ELAPSED(WHEN) GT DATE(DEC)
            AND WHENDONE(DECSP,WHEN) GT 0 ),
         SUM((CLS,OWNER,SITE,SPECIES,MIC)$ (
            yespolicy(policy,cls,owner,species,site,mic) gt 0 and
            ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0),
            GROWCOST(REGS,CLS,MIC,SPECIES)
           *(policyinc(policy,decsp,"maintain"))
           *NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECSP,policy)   ))))

 =l=    money(policy);

forcedland(policy) $ ( examine(policy) gt 0 and landmin(policy) gt 0)..
*land ESTABLISHed
sum((REGS,dec)$(policyinc(policy,dec,"forceland") gt 0
            and forceland(regs,policy) gt 0),
      SUM(WHEN$(ELAPSED(WHEN) NE 0
               AND WHENDONE(DEC,WHEN) GT 0),
          SUM((CLS,OWNER,SPECIES,site,MIC)
              $(ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
            and yespolicy(policy,cls,owner,species,site,mic) gt 0),
             NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DEC,policy))))
 =g=    landmin(policy);

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT
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   DEMAND BALANCE FOR FOREST PRODUCTS

   THIS EQUATION IS DEFINED FOR A REGION, AND PRODUCT

   THE $ NOTATION AFTER THE WHEN LINE CAUSES THE ACTIVITY TO ONLY BE
       PRESENT WHEN IT IS HARVESTED THIS DEC

   THE $ NOTATION AFTER THE DEMANDFOR LINE CAUSES THE ACTIVITY TO
       ONLY BE PRESENT WHEN IT IS IN DEMAND
$OFFTEXT

  PRODBALDEM(PRODS,DEC)$(YESFOR GT 0 AND
       (FPDEMAND(PRODS,DEC,"SLOPE") NE 0
     OR FPDEMAND(PRODS,DEC,"FIXP") NE 0
     OR FPDEMAND(PRODS,DEC,"MINQ") NE 0))..

- sum(regs,TRANSFOR(REGS,PRODS,DEC)$(  transcost(regs,prods) NE 0
                                   and yesitis(regs,prods) ne 0))
+ (DEMANDFOR(PRODS,DEC)
          $(SEPFOR EQ 0 OR FPDEMAND(PRODS,DEC,"SLOPE") EQ 0)+
   SUM(STEPS, DEMANDFORS(PRODS,DEC,STEPS)
       *QINC(STEPS)*DEMANDQ(PRODS,DEC)/SCFOR)
        $(SEPFOR GT 0 AND FPDEMAND(PRODS,DEC,"SLOPE") NE 0))$
            (   FPDEMAND(PRODS,DEC,"SLOPE") NE 0
             OR FPDEMAND(PRODS,DEC,"FIXP") NE 0
             OR FPDEMAND(PRODS,DEC,"MINQ") NE 0)
+ SUM(PRODUCTS$(   (   FPDEMAND(PRODS,DEC,"SLOPE") NE 0
                    OR FPDEMAND(PRODS,DEC,"FIXP") NE 0
                    OR FPDEMAND(PRODS,DEC,"MINQ") NE 0) ),
       PRODUCTSUB(PRODS,PRODUCTS,DEC)  $SUBS(PRODS,PRODUCTS)
      -PRODUCTSUB(PRODUCTS,PRODS,DEC)$SUBS(PRODUCTS,PRODS))
  =L=
      0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   FOREST DOMESTIC DEMAND CONVEXITY FOR SEPARABLE PROGRAMMING

  CPRDBALDEM(PRODS,DEC)
    $(YESFOR GT 0 AND SEPFOR GT 0
          AND FPDEMAND(PRODS,DEC,"SLOPE") NE 0)..
  SUM(STEPS, DEMANDFORS(PRODS,DEC,STEPS))=L= 1.;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   SUPPLY BALANCE FOR FOREST PRODUCTS

   THIS EQUATION IS DEFINED FOR A REGION, AND PRODUCT

   THE $ NOTATION AFTER THE WHEN LINE CAUSES THE ACTIVITY TO ONLY BE
       PRESENT WHEN IT IS HARVESTED THIS DEC

   THE $ NOTATION AFTER THE DEMANDFOR LINE CAUSES THE ACTIVITY TO ONLY BE
       PRESENT WHEN IT IS IN DEMAND

$OFFTEXT

PRODBALSUP(REGS,PRODS,DEC)$(YESFOR GT 0 AND YESITIS(REGS,PRODS))..

 - SUM(WHEN$(TODAY+ELAPSED(WHEN) EQ DATE(DEC)),
       SUM((CLS,OWNER,SITE,COHORT,MIC,SPECIES)
              $ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
           EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)*
           EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,WHEN)))
 - SUM(OLDDEC$(DATE(OLDDEC) LE DATE(DEC)),
       SUM(WHEN$ (    DATE(OLDDEC)+ELAPSED(WHEN) EQ DATE(DEC)
                  AND WHENDONE(OLDDEC,WHEN)      GT 0),
           SUM((CLS,OWNER,SITE,MIC,SPECIES,policy)$(
                             examine(policy) gt 0
             and ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0),
               NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,policy)*
               yespolicy(policy,cls,owner,species,site,mic)
              *policyinc(policy,olddec,"exist")*
               NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN)  )))
 +              TRANSFOR(REGS,PRODS,DEC)$(transcost(regs,prods) NE 0)
 + SUM(TRADEREG$TRADECOST(REGS,TRADEREG,PRODS),
         TRADEFPTRN(REGS,TRADEREG,PRODS,DEC,"EXPORT")$
            (TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"INTERCEPT") GT 0  OR
             TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"MINQ")      GT 0  OR
             TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"FIXP")      GT 0))
- SUM(TRADEREG$TRADECOST(regs,TRADEREG,PRODS),
      TRADEFPTRN(REGS,TRADEREG,PRODS,DEC,"IMPORT")$
         (TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE") GT 0  OR
          TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"MINQ") GT 0  OR
          TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"FIXP") GT 0) )
    +FUELSUB(REGS,DEC)*FUELSUBDAT(PRODS)$YESITIS(REGS,"FUELHW")
 =L=
   SUM(POWNER,PUBSUP(POWNER,REGS,DEC,PRODS))/SCFOR;


*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   CAPACITY BALANCE FOR FOREST PROCESSING

   THIS EQUATION IS DEFINED FOR A REGION, AND PRODUCT

   THE $ NOTATION AFTER THE WHEN LINE CAUSES THE ACTIVITY TO ONLY BE
       PRESENT WHEN THERE IS CAPACITY AND DEMAND

$OFFTEXT
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```
CAPACLIM(PRODS,DEC)$((CAPACITY(PRODS,"NOWINPLACE") GT 0) AND
                           (   FPDEMAND(PRODS,DEC,"SLOPE") NE 0
                            OR FPDEMAND(PRODS,DEC,"FIXP")  NE 0
                            OR FPDEMAND(PRODS,DEC,"MINQ") NE 0)
                          AND YESFOR GT 0  )..

   DEMANDFOR(PRODS,DEC)
        $(SEPFOR EQ 0 OR FPDEMAND(PRODS,DEC,"SLOPE") EQ 0)+
   SUM(STEPS, DEMANDFORS(PRODS,DEC,STEPS)
            *QINC(STEPS)*DEMANDQ(PRODS,DEC)/SCFOR)
                $(SEPFOR GT 0 AND FPDEMAND(PRODS,DEC,"SLOPE") NE 0)
   =L=
   CAPACITY(PRODS,"NOWINPLACE")/SCFOR
               *(1-CAPACITY(PRODS,"EXISTDEPRC"))**(10*ORD(DEC))
  +SUM(DECSP$(ORD(DECSP) LE ORD(DEC)),BUILDCAP(PRODS,DECSP)*
           (1-CAPACITY(PRODS,"NEWDEPREC"))**(10*(ORD(DEC)-ORD(DECSP))));

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   IMPORT AND EXPORT BALANCE

 TRADEBAL(TRADEREG,PRODS,DEC)$(
         (TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"INTERCEPT") GT 0  OR
          TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"MINQ") GT 0  OR
          TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"FIXP") GT 0 OR
          TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"INTERCEPT") GT 0  OR
          TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"MINQ") GT 0  OR
          TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"FIXP") GT 0)
          AND YESFOR GT 0)..
   + (SUM(REG$YESITIS(REG,PRODS), TRADEFPTRN(REG,TRADEREG,PRODS,DEC,"IMPORT")
                 $TRADECOST(REG,TRADEREG,PRODS))
   - (TRADEQUAN(TRADEREG,PRODS,DEC,"IMPORT")$(SEPFOR EQ 0 OR
              TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE") EQ 0)
   + SUM(STEPS,TRADEQUANS(TRADEREG,PRODS,DEC,"IMPORT",STEPS)*
        TRADEQ(TRADEREG,PRODS,DEC,"IMPORT")*QINC(STEPS)/SCFOR)$
        (SEPFOR GT 0 AND TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE") GT 0)))
           $(TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"SLOPE") GT 0  OR
             TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"MINQ") GT 0  OR
             TRADFOR(TRADEREG,"IMPORT",PRODS,DEC,"FIXP") GT 0)
   + (- SUM(REG$YESITIS(REG,PRODS),
            TRADEFPTRN(REG,TRADEREG,PRODS,DEC,"EXPORT")
               $TRADECOST(REG,TRADEREG,PRODS))
   + (TRADEQUAN(TRADEREG,PRODS,DEC,"EXPORT")$
           (SEPFOR EQ 0 OR TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE") EQ 0)
   + SUM(STEPS,TRADEQUANS(TRADEREG,PRODS,DEC,"EXPORT",STEPS)*
         TRADEQ(TRADEREG,PRODS,DEC,"EXPORT")*QINC(STEPS)/SCFOR)$
        (SEPFOR GT 0 AND TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE") LT 0 ))
        )$  (TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"SLOPE") LT 0  OR
             TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"MINQ") GT 0  OR
             TRADFOR(TRADEREG,"EXPORT",PRODS,DEC,"FIXP") GT 0)
   =L= 0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*TRADE CONVEXITY

 CTRADEBAL(TRADEREG,PRODS,DEC,TRADE)$(YESFOR GT 0 AND SEPFOR GT 0 AND
    ABS(TRADFOR(TRADEREG,TRADE,PRODS,DEC,"SLOPE")) GT 0)..
      SUM(STEPS,TRADEQUANS(TRADEREG,PRODS,DEC,TRADE,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*  FOREST PRODUCTION COST ACCOUNTING

 COSTBAL(REGS,DEC)$ YESFOR..

* COST FOR AN INITIAL STAND NOT YET HARVESTED
 +SUM(WHEN$(TODAY+ELAPSED(WHEN) GT DATE(DEC)),
     SUM((CLS,OWNER,SITE,COHORT,MIC,SPECIES)
          $  ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
        GROWCOST(REGS,CLS,MIC,SPECIES)*
        EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)))
* COST FOR HARVESTING AN EXISTING STAND THIS DEC
 +SUM(WHEN$(TODAY+ELAPSED(WHEN) EQ DATE(DEC)),
      SUM((CLS,OWNER,SPECIES,SITE,COHORT,MIC)
           $  ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
        (SUM(PRODS$YESITIS(REGS,PRODS),HARVCOST(PRODS,REGS)
            *EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,WHEN))
         +GROWCOST(REGS,CLS,MIC,SPECIES)*4/10)
         *EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)))
* COST TO ESTABLISH A NEW STAND
 +SUM(DECSP$(DATE(DECSP) EQ DATE(DEC)),
      SUM(WHEN$(DATE(DECSP)+ELAPSED(WHEN) NE DATE(DEC)
               AND WHENDONE(DECSP,WHEN) GT 0),
          SUM((CLS,OWNER,SITE,SPECIES,MIC,policy)
              $(ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
                         and examine(policy) gt 0),
             (GROWCOST(REGS,CLS,MIC,SPECIES)*4/10
             *(1-policyinc(policy,decsp,"maintain"))
             +ESTCOST(REGS,CLS,MIC,SPECIES)
             *(1-policyinc(policy,decsp,"establish")))
             *NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECSP,policy)*
              yespolicy(policy,cls,owner,species,site,mic)
             *policyinc(policy,decsp,"exist"))))
* COST TO MAINTAIN A NEW STAND ESTABLISHED BUT NOT YET AT HARVESTABLE AGE.
 +SUM(DECSP$(DATE(DECSP) LE DATE(DEC)),
      SUM(WHEN$(DATE(DECSP)+ELAPSED(WHEN) GT DATE(DEC)
            AND WHENDONE(DECSP,WHEN) GT 0),
         SUM((CLS,OWNER,SITE,SPECIES,MIC,policy)$(
            ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
            and   examine(policy) gt 0),
            GROWCOST(REGS,CLS,MIC,SPECIES)
           *(1-policyinc(policy,decsp,"maintain"))
           *NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECSP,policy)*
            yespolicy(policy,cls,owner,species,site,mic)
```

```
           *policyinc(policy,decsp,"exist"))))
* COST TO HARVEST A NEW STAND
 + SUM(DECSP$(DATE(DECSP) LE DATE(DEC)),
      SUM(WHEN$(DATE(DECSP)+ELAPSED(WHEN) EQ DATE(DEC)
              AND WHENDONE(DECSP,WHEN) GT 0),
         SUM((CLS,OWNER,SITE,SPECIES,MIC,policy)$
             (ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
              and examine(policy) gt 0),
             (SUM(PRODS$YESITIS(REGS,PRODS),HARVCOST(PRODS,REGS)
                 *NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN))
            +GROWCOST(REGS,CLS,MIC,SPECIES)*4/10)
             *NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECSP,policy)*
              yespolicy(policy,cls,owner,species,site,mic)
             *policyinc(policy,decsp,"exist"))))
  =E=
   COSTS(REGS,DEC)  ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   NATIONAL LEVEL ENDING INVENTORY

* FOR THE NATIONAL DEMAND CASE, TERMVOLN IS ACTUALLY THE FULLY REGULATED DECADE
*   FLOW (HARVEST) VOLUME

NENDINVEN(PRODS)$    (TERMVALUE(PRODS) GT 0
                      AND SUM((PARAMS,DECS),FPDEMAND(PRODS,DECS,PARAMS)) GT 0
                      AND YESFOR GT 0 )..

    TERMVOLN(PRODS)$(YESFOR GT 0 AND SEPFOR EQ 0 OR
       SUM(DEC$(ORD(DEC) EQ CARD(DEC)),FPDEMAND(PRODS,DEC,"SLOPE")) EQ 0)
  + SUM(STEPS,TERMVOLNS(PRODS,STEPS)*QINC(STEPS)/SCFOR*
       TERMVOLQ(PRODS))$(SEPFOR GT 0 AND
       SUM(DEC$(ORD(DEC) EQ CARD(DEC)),FPDEMAND(PRODS,DEC,"SLOPE")) NE 0)
 -SUM(REGS,
*the following code replaces  TERMVOL(REGS,PRODS)
   (2.0/(ROTATION(REGS)/10))*(
  +  SUM(WHEN$(TODAY+ELAPSED(WHEN) GT LASTDAY),
       SUM((CLS,OWNER,SPECIES,SITE,COHORT,MIC)$
              ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
           EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)*
           EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,WHEN)))
  +  SUM(OLDDEC,
      SUM((WHEN,TIME2)$(WHENDONE(OLDDEC,WHEN) GT 0 AND
            ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY EQ 10*(ORD(TIME2)-1))
         OR ((DATE(OLDDEC)+ELAPSED(WHEN)-LASTDAY GT 10*(ORD(TIME2)-1))
         AND (ORD(TIME2) EQ CARD(TIME2))))),
         SUM((CLS,OWNER,SPECIES,SITE,MIC,policy)$(
              ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
                          and examine(policy) gt 0),
              NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,OLDDEC,policy)*
              yespolicy(policy,cls,owner,species,site,mic)
             *policyinc(policy,olddec,"exist")*
              NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,TIME2))   ))
         +ENDFUELSUB(REGS)*FUELSUBDAT(PRODS)$YESITIS(REGS,"FUELHW"))
*the above code replaces   TERMVOL(REGS,PRODS)
   $(YESITIS(REGS,PRODS) GT 0 AND YESFOR GT 0 ))
  =L= 0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   CONVEXITY FOR NATIONAL LEVEL ENDING INVENTORY

 CNENDINVEN(PRODS)$(YESFOR GT 0 AND SEPFOR GT 0 AND
  SUM(DEC$(ORD(DEC) EQ CARD(DEC)),FPDEMAND(PRODS,DEC,"SLOPE")) LT 0)..
       SUM(STEPS,TERMVOLNS(PRODS,STEPS)) =L= 1;


*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   BALANCE EQUATION FOR LAND TRANSFERING TO AND FROM AG

   THIS EQUATION IS DEFINED FOR A REGION, CLS, AND DEC

   THIS EQUATION EUALIZES SUMS TRANFERRING BUT DOES NOT HAVE OWNERSHIP
        SiTE OR SPEC SINCE THEY ARE NOT ACCOUNTED FOR IN THE AG MODEL
$OFFTEXT

 TRNtoLDBAL(REGS,CLS,DEC)
   $(yesag*yesfor gt 0 and
    sum((owner,site,spec),whentran(regs,cls,site,owner,spec,"toag")) gt 0)..

 - SUM(SPEC,CONVRTTOAG(REGS,CLS,DEC,SPEC)
               $sum((owner,site),whentran(regs,cls,site,owner,spec,"toag")))
 + SUM(THREE$YESCONLND(REGS,CLS,three),LANDTOAG(REGS,CLS,DEC,THREE))*
             SUM(LNDMATfrfr(LANDTYPE,CLS),SCALE(LANDTYPE)/SCFOR)
  =L= 0 ;

 TRNfrLDBAL(REGS,CLS,DEC)
  $(yesag * yesfor gt 0 and
   sum((owner,site,spec),whentran(regs,cls,site,owner,spec,"fromag")) gt 0)..

 +SUM(SPEC$sum((owner,site),whentran(regs,cls,site,owner,spec,"fromag")),
           CONVRTFRAG(REGS,CLS,DEC,SPEC)  )
 - LANDFROMAG(REGS,CLS,DEC)
         *SUM(LNDMATfrfr(LANDTYPE,CLS),SCALE(LANDTYPE)/SCFOR)

  =L= 0 ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   LIMIT ON LAND MOVING TO AGRICULTURE EQUATION
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```
   THIS EQUATION IS DEFINED FOR A REGION,TYPE OF LAND, ACROSS ALL DEC

   THE EQUATION LIMITS THE LAND IN THREE CLASSES

   THE $ NOTATION LIMITS THE CONSTRAINT TO APPEAR ONLY WHEN THERE IS LAND

$OFFTEXT

 LANDTRNLIM(REGS,CLS,THREE)
  $(sum((owner,site,spec)
         ,whentran(regs,cls,site,owner,spec,"toag")) gt 0 and
 YESCONLND(REGS,CLS,three) gt 0 AND YESFOR*YESAG GT 0)..
      SUM(DEC,LANDTOAG(REGS,CLS,DEC,THREE))
    =L=
      CONVERT(REGS,CLS,"CQUAN",THREE)/
         SUM(LNDMATfrfr(LANDTYPE,CLS),SCALE(LANDTYPE));

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
$ONTEXT

   LIMIT ON LAND MOVING FROM AGRICULTURE EQUATION

   THIS EQUATION IS DEFINED FOR A REGION,TYPE OF LAND, ACROSS ALL DEC

   THE $ NOTATION LIMITS THE CONSTRAINT TO APPEAR ONLY WHEN THERE IS LAND

$OFFTEXT

 AGLDTRNLIM(REGS,CLS)
     $(sum((owner,site,spec),whentran(regs,cls,site,owner,spec,"fromag"))
                       AND YESFOR*YESAG GT 0)..
      SUM(DEC,LANDFROMAG(REGS,CLS,DEC))
     -SUM((DEC,THREE)$yesconlnd(regs,cls,three)
               ,LANDTOAG(REGS,CLS,DEC,THREE))
    =L=
      AGCONVERT(REGS,CLS);

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*AGRICULTURAL PRIMARY BALANCE

 PRIMARYBAL(DEC,PRIMARY)$(YESAG GT 0)..
        - SUM(REGS,
           SUM((CROP,WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
               CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
              *SCALPROD
              *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"NONPART",TECH)
              *AGQDYN(PRIMARY,DEC)
             + CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
              *SCALPROD
              *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"NONPART",TECH)
              *AGQDYN(PRIMARY,DEC)
              *(1.0-NEWFPPART(REGS,CROP))
             + CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
              *SCALPROD
              *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"PARTICIP",TECH)
              *AGQDYN(PRIMARY,DEC)
              *NEWFPPART(REGS,CROP) * (1.0-FARMPROD("SETASIDE",CROP)
                    -FARMPROD("DIVERSION",CROP)-FARMPROD("50-92",CROP))
              * (1.0-FARMPROD("PERCNTPAID",CROP))    )
              /SCALE(PRIMARY)
         + SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) GT 0.0 AND
                       FARMPROD("FPYIELD",CROP)*FARMPROGY(DEC) LE 1.0),
                CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
               *SCALPROD
                 *NEWFPPART(REGS,CROP) * (1.0-FARMPROD("SETASIDE",CROP)
                    -FARMPROD("DIVERSION",CROP)-FARMPROD("50-92",CROP))
                 * FARMPROD("PERCNTPAID",CROP)
              /SCALE(PRIMARY)
                 *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"PARTICIP",TECH)
              *AGQDYN(PRIMARY,DEC)
                 *(1.0-FARMPROD("FPYIELD",CROP))    )
         + SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                *SCALPROD
                *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"BASE",TECH)
              *AGQDYN(PRIMARY,DEC) )
              /SCALE(PRIMARY)
         + SUM((ANIMAL,LIVETECH),
                 LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)
                *SCALLIVE
                *NEWLIVEBUD(PRIMARY,REGS,ANIMAL,LIVETECH)
              )/SCALE(PRIMARY)  )
         - DEFPRODN(DEC,PRIMARY)$(FARMPROD("SLIPPAGE",PRIMARY) GT 0 AND
                         FARMPROD("TARGET",PRIMARY)*FARMPROGY(DEC) GT 0 )
         + DEMANDP(DEC,PRIMARY)$(SEPAG LE 0
                         OR PDEMAND(PRIMARY,"ELASTICITY") GT -.05
                         AND PDEMAND(PRIMARY,"QUANTITY") GT 0)
         + SUM(STEPS$(PDEMAND(PRIMARY,"TFAC") GE 1/QINC(STEPS)
                    AND PDEMAND(PRIMARY,"TFAC") GE QINC(STEPS)),
              PDEMAND(PRIMARY,"QUANTITY")*QINC(STEPS)
           *  demandGRW(PRIMARY,DEC)
           *  DEMANDPS(DEC,PRIMARY,STEPS))$((SEPAG GT 0
                       AND PDEMAND(PRIMARY,"ELASTICITY") LE -.05)
                       AND PDEMAND(PRIMARY,"QUANTITY") GT 0)/SCALE(PRIMARY)
         + EXPORTP(DEC,PRIMARY)$((SEPAG LE 0
                         OR PEXPORT(PRIMARY,"ELASTICITY") GT -.05)
                         AND PEXPORT(PRIMARY,"QUANTITY") GT 0)
         + SUM(STEPS$(PEXPORT(PRIMARY,"TFAC") GE 1/QINC(STEPS)
                 AND PEXPORT(PRIMARY,"TFAC") GE QINC(STEPS)),
              PEXPORT(PRIMARY,"QUANTITY")*QINC(STEPS)
           *  EXPORTGRW(PRIMARY,DEC)*  EXPORTPS(DEC,PRIMARY,STEPS))
                      $(SEPAG GT 0
```

```
                       AND PEXPORT(PRIMARY,"ELASTICITY") LE -.05
                       AND PEXPORT(PRIMARY,"QUANTITY") GT 0)/SCALE(PRIMARY)

         - IMPORTP(DEC,PRIMARY)$((SEPAG LE 0
                         OR PIMPORT(PRIMARY,"ELASTICITY") LE .05)
                         AND PIMPORT(PRIMARY,"QUANTITY") GT 0)
         - SUM(STEPS,
             PIMPORT(PRIMARY,"QUANTITY")*QINC(STEPS)
           * IMPORTGRW(PRIMARY,DEC)*  IMPORTPS(DEC,PRIMARY,STEPS))
                      $(SEPAG GT 0
                       AND PIMPORT(PRIMARY,"ELASTICITY") GT .05
                       AND PIMPORT(PRIMARY,"QUANTITY") GT 0)/SCALE(PRIMARY)
         + SUM(PROCESSALT,
                 PROCESS(DEC,PROCESSALT)*PROCBUD(PRIMARY,PROCESSALT)
                   *(1$(PROCBUD(PRIMARY,PROCESSALT) LT 0)
                   + 1$(PROCBUD(PRIMARY,PROCESSALT) GE 0)))
                     /SCALE(PRIMARY)*SCALPROC
         + CCCLOANP(DEC,PRIMARY)
              $(FARMPROD("LOANRATE",PRIMARY)*FARMPROGY(DEC) GT 0
                     AND    FARMPROD("MKTLOANY-N",PRIMARY) LT 1.0)
          =L= 0. ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
* AGRICULTURAL PRIMARY DOMESTIC DEMAND CONVEXITY

    CPRIBALDOM(DEC,PRIMARY)$(YESAG GT 0 AND
                             SEPAG GT 0 AND PDEMAND(PRIMARY,"QUANTITY") GT 0
                         AND PDEMAND(PRIMARY,"ELASTICITY") LE -.05)..
      SUM(STEPS$(PDEMAND(PRIMARY,"TFAC") GE 1/QINC(STEPS)
              AND PDEMAND(PRIMARY,"TFAC") GE QINC(STEPS)),
                  DEMANDPS(DEC,PRIMARY,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL PRIMARY EXPORT DEMAND CONVEXITY

    CPRIBALEXP(DEC,PRIMARY)$(YESAG GT 0 AND
                             SEPAG GT 0 AND PEXPORT(PRIMARY,"QUANTITY") GT 0
                         AND PEXPORT(PRIMARY,"ELASTICITY") LE -.05)..
      SUM(STEPS$(PEXPORT(PRIMARY,"TFAC") GE 1/QINC(STEPS)
               AND PEXPORT(PRIMARY,"TFAC") GE QINC(STEPS)),
                  EXPORTPS(DEC,PRIMARY,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL PRIMARY IMPORT SUPPLY CONVEXITY

    CPRIBALIMP(DEC,PRIMARY)$(YESAG GT 0 AND
                             SEPAG GT 0 AND PIMPORT(PRIMARY,"QUANTITY") GT 0
                         AND PIMPORT(PRIMARY,"ELASTICITY") GT .05)..
      SUM(STEPS,  IMPORTPS(DEC,PRIMARY,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL PRIMARY CROPS ELIGABLE FOR DEFICIENCY PAYMENTS BALANCE

    FRMPROG(DEC,CROP)$(FARMPROD("TARGET",CROP) GT 0
               AND YESAG GT 0)..
   - SUM((REGS,WTECH,TECH),
           CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
         * SCALPROD
         *  NEWFPPART(REGS,CROP)
         *  FARMPROD("PERCNTPAID",CROP) * AGQDYN(CROP,DEC)
         *     min(1.0, FARMPROD("FPYIELD",CROP))
                   *NEWBUDDATA(CROP,REGS,CROP,WTECH,"PARTICIP",TECH))
         / SCALE(CROP)
   +  DEFPRODN(DEC,CROP)
   =L=  0.  ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL ELIGABILITY FOR 50/92 PAYMENTS BALANCE

 P5092(DEC,CROP)$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND YESAG GT 0)..
   - SUM((REGS,WTECH,TECH), CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
        *SCALPROD
        *NEWFPPART(REGS,CROP)*FARMPROD("50-92",CROP)
        *FARMPROD("FPYIELD",CROP)
        /SCALE(CROP)
       *NEWBUDDATA(CROP,REGS,CROP,WTECH,"PARTICIP",TECH) * AGQDYN(CROP,DEC))
        *0.92
   +PRDN5092(DEC,CROP)
     =L=  0.  ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL ELIGABILITY FOR PAID DIVERSION PAYMENTS BALANCE

DIVERT(DEC,CROP)$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND YESAG GT 0)..
   - SUM((REGS,WTECH,TECH), CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
        *SCALPROD
        *NEWFPPART(REGS,CROP)*FARMPROD("DIVERSION",CROP)
        *FARMPROD("FPYIELD",CROP)
        *NEWBUDDATA(CROP,REGS,CROP,WTECH,"PARTICIP",TECH)* AGQDYN(CROP,DEC) )
        /SCALE(CROP)
  + DIVPRODN(DEC,CROP)
   =L=  0.  ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL ELIGABILITY FOR UNHARVESTED ACRES PAYMENTS BALANCE

 UNHARVEST(DEC,CROP)$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND
              FARMPROD("UNHARVACR",CROP) GT 0 AND YESAG GT 0)..
   - SUM((REGS,WTECH,TECH),
          CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
        * SCALPROD
        * NEWFPPART(REGS,CROP)
```

```
        * FARMPROD("PERCNTPAID",CROP)
        * FARMPROD("UNHARVACR",CROP) *FARMPROD("FPYIELD",CROP)
        * NEWBUDDATA(CROP,REGS,CROP,WTECH,"PARTICIP",TECH)*AGQDYN(CROP,DEC))
        / SCALE(CROP)
   +UNHARV(DEC,CROP)
   =L=  0.  ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL ELIGABILITY FOR YIELD BELOW FP YIELD PAYMENTS BALANCE

 ARTIFICIAL(DEC,CROP)$(FARMPROD("TARGET",CROP)*FARMPROGY(DEC) GT 0 AND
              FARMPROD("FPYIELD",CROP) GT 1.0 AND YESAG GT 0)..
   - SUM((REGS,WTECH,TECH),
           CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
         * SCALPROD
         * NEWFPPART(REGS,CROP)
         * FARMPROD("PERCNTPAID",CROP)
         * (FARMPROD("FPYIELD",CROP)-1.0)
         * NEWBUDDATA(CROP,REGS,CROP,WTECH,"PARTICIP",TECH)* AGQDYN(CROP,DEC)
           )/ SCALE(CROP)
   + ARTIF(DEC,CROP)
   =L=  0.  ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL SECONDARY CROP BALANCE

 SECONDBAL(DEC,SECONDARY)$(YESAG GT 0)..
         +SUM(REGS,
             SUM((CROP,WTECH,CTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
                *SCALPROD
                *NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"PARTICIP",TECH)
         *( AGQDYN(SECONDARY,DEC)
          $(NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"PARTICIP",TECH) LT 0)
            +1$(NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"PARTICIP",TECH) GE 0)) +
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
               *SCALPROD
                *NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"NONPART",TECH)
      *( AGQDYN(SECONDARY,DEC)
      $(NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"NONPART",TECH) LT 0)
            +1$(NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"NONPART",TECH) GE 0) )
  )
                /SCALE(SECONDARY)
             +SUM((CROP,WTECH,CTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                *SCALPROD
                *NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"BASE",TECH)
   *( AGQDYN(SECONDARY,DEC)
            $(NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"BASE",TECH) LT 0)
            +1$(NEWBUDDATA(SECONDARY,REGS,CROP,WTECH,"BASE",TECH) GE 0) )
  )
                /SCALE(SECONDARY)
             +SUM((ANIMAL,LIVETECH),
                  LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)
                 *SCALLIVE
                 *NEWLIVEBUD(SECONDARY,REGS,ANIMAL,LIVETECH)
        *( AGQDYN(SECONDARY,DEC)
              $(NEWLIVEBUD(SECONDARY,REGS,ANIMAL,LIVETECH) LT 0)
            +1$(NEWLIVEBUD(SECONDARY,REGS,ANIMAL,LIVETECH) GE 0))
     )
                /SCALE(SECONDARY) )
      +DEMANDS(DEC,SECONDARY)$(SEPAG LE 0
                         OR SDEMAND(SECONDARY,"ELASTICITY") GT -.05
                         AND SDEMAND(SECONDARY,"QUANTITY") GT 0)
      +SUM(STEPS$(SDEMAND(SECONDARY,"TFAC") GE 1/QINC(STEPS) AND
                  SDEMAND(SECONDARY,"TFAC") GE QINC(STEPS)),
            SDEMAND(SECONDARY,"QUANTITY")*QINC(STEPS)
           *DEMANDGRW(SECONDARY,DEC)*  DEMANDSS(DEC,SECONDARY,STEPS))
            $((SEPAG GT 0
                    AND SDEMAND(SECONDARY,"ELASTICITY") LE -.05)
                    AND SDEMAND(SECONDARY,"QUANTITY") GT 0)/SCALE(SECONDARY)
      +EXPORTS(DEC,SECONDARY)$(SEPAG LE 0
                         OR SEXPORT(SECONDARY,"ELASTICITY") GT -.05
                         AND SEXPORT(SECONDARY,"QUANTITY") GT 0)
      +SUM(STEPS$(SEXPORT(SECONDARY,"TFAC") GE 1/QINC(STEPS)
              AND SEXPORT(SECONDARY,"TFAC") GE QINC(STEPS)),
            SEXPORT(SECONDARY,"QUANTITY")*QINC(STEPS)
           *EXPORTGRW(SECONDARY,DEC)*  EXPORTSS(DEC,SECONDARY,STEPS))
                       $((SEPAG GT 0
                       AND SEXPORT(SECONDARY,"ELASTICITY") LE -.05)
                       AND SEXPORT(SECONDARY,"QUANTITY") GT 0)/SCALE(SECONDARY)
      -IMPORTS(DEC,SECONDARY)$((SEPAG LE 0
                         OR SIMPORT(SECONDARY,"ELASTICITY") LT .05)
                         AND SIMPORT(SECONDARY,"QUANTITY") GT 0)
      -SUM(STEPS,
            SIMPORT(SECONDARY,"QUANTITY")*QINC(STEPS)
           *IMPORTGRW(SECONDARY,DEC)*  IMPORTSS(DEC,SECONDARY,STEPS))
                       $((SEPAG GT 0
                       AND SIMPORT(SECONDARY,"ELASTICITY") GT .05)
                       AND SIMPORT(SECONDARY,"QUANTITY") GT 0)/SCALE(SECONDARY)
          -SUM(PROCESSALT,PROCESS(DEC,PROCESSALT)
             *PROCBUD(SECONDARY,PROCESSALT)
        *( AGQDYN(SECONDARY,DEC)
              $(PROCBUD(SECONDARY,PROCESSALT) LT 0)
            +1$(PROCBUD(SECONDARY,PROCESSALT) GE 0))
                /SCALE(SECONDARY))*SCALPROC
          +CCCLOANS(DEC,SECONDARY)$
            (FARMPROD("LOANRATE",SECONDARY)*FARMPROGY(DEC) GT 0  AND
                                 FARMPROD("MKTLOANY-N",SECONDARY) LT 1.0)
          =L= 0. ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
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*   AGRICULTURAL SECONDARY CROP DOMESTIC DEMAND CONVEXITY

    CSECBALDOM(DEC,SECONDARY)$(YESAG GT 0 AND
                             SEPAG GT 0 AND SDEMAND(SECONDARY,"QUANTITY") GT 0
                         AND SDEMAND(SECONDARY,"ELASTICITY") LE -.05)..
      SUM(STEPS$(SDEMAND(SECONDARY,"TFAC") GE 1/QINC(STEPS)
              AND SDEMAND(SECONDARY,"TFAC") GE QINC(STEPS)),
                  DEMANDSS(DEC,SECONDARY,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL SECONDARY CROP EXPORT DEMAND CONVEXITY

    CSECBALEXP(DEC,SECONDARY)$(YESAG GT 0 AND
                             SEPAG GT 0 AND SEXPORT(SECONDARY,"QUANTITY") GT 0
                         AND SEXPORT(SECONDARY,"ELASTICITY") LE -.05)..
      SUM(STEPS$(SEXPORT(SECONDARY,"TFAC") GE 1/QINC(STEPS)
             AND SEXPORT(SECONDARY,"TFAC") GE QINC(STEPS)),
                  EXPORTSS(DEC,SECONDARY,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL SECONDARY CROP DOMESTIC DEMAND CONVEXITY

    CSECBALIMP(DEC,SECONDARY)$(YESAG GT 0 AND
                             SEPAG GT 0 AND SIMPORT(SECONDARY,"QUANTITY") GT 0
                         AND SIMPORT(SECONDARY,"ELASTICITY") GT .05)..
      SUM(STEPS, IMPORTSS(DEC,SECONDARY,STEPS))=L=1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   MAXIMUM LAND AVAILABILITY BY REGION

 MAXLAND(DEC,REGS,LANDTYPE)$(NEWLANDAVL(REGS,LANDTYPE)GT 0 AND YESAG GT 0)..
         SUM((CROP,WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
             CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
        *SCALPROD
            *NEWBUDDATA(LANDTYPE,REGS,CROP,WTECH,"PARTICIP",TECH)
            /SCALE(LANDTYPE)
            + CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
            *SCALPROD
            *NEWBUDDATA(LANDTYPE,REGS,CROP,WTECH,"NONPART",TECH)
            /SCALE(LANDTYPE)  ) +
         SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.),
             CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
            *SCALPROD
            *NEWBUDDATA(LANDTYPE,REGS,CROP,WTECH,"BASE",TECH)
            /SCALE(LANDTYPE)   ) +
         SUM((ANIMAL,LIVETECH),
             LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)
            *SCALLIVE
            *NEWLIVEBUD(LANDTYPE,REGS,ANIMAL,LIVETECH)
            /SCALE(LANDTYPE))
+ (SUM(CLS$(1$lndmatfrfr(landtype,cls)*sum((owner,site,spec)
         ,whentran(regs,cls,site,owner,spec,"toag")) gt 0 ),
      - SUM(DECSP$(ORD(DECSP) LE ORD(DEC)),
            SUM(THREE,LANDTOAG(REGS,CLS,DECSP,THREE)
                    $YESCONLND(REGS,CLS,three))))
+ SUM(CLS$( 1$lndmattofr(landtype,cls)*
       sum((site,spec),whentran(regs,cls,site,"op",spec,"fromag") )),
       SUM(DECSP$(ORD(DECSP) LE ORD(DEC)),LANDFROMAG(REGS,CLS,DECSP) )))
       $yesfor
      =L=
         NEWLANDAVL(REGS,LANDTYPE)*AGLANDGRW(REGS,LANDTYPE,DEC)
            /SCALE(LANDTYPE) ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL LAND BALANCE BY REGION

 LAND(DEC,REGS,LANDTYPE)$(YESAG GT 0 AND NEWLANDAVL(REGS,LANDTYPE) GT 0)..
        ( SUM((CROP,WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
                *SCALPROD
                *NEWBUDDATA(LANDTYPE,REGS,CROP,WTECH,"PARTICIP",TECH)+
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
                *SCALPROD
                *NEWBUDDATA(LANDTYPE,REGS,CROP,WTECH,"NONPART",TECH)  ) +
             SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                *SCALPROD
                *NEWBUDDATA(LANDTYPE,REGS,CROP,WTECH,"BASE",TECH)     ) +
             SUM((ANIMAL,LIVETECH),
                 LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)
                *SCALLIVE
                *NEWLIVEBUD(LANDTYPE,REGS,ANIMAL,LIVETECH)))
          /SCALE(LANDTYPE)
        -LANDSUPPLY(DEC,REGS,LANDTYPE)$(SEPAG LE 0 OR
                 NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") LE 0.05
                AND NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY") GT  0)
        -SUM(STEPS,
             NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY")*AGLANDGRW(REGS,LANDTYPE,DEC)
           * QINC(STEPS)*LANDSUPPLS(DEC,REGS,LANDTYPE,STEPS)/SCALE(LANDTYPE)
             )$(SEPAG GT 0 AND NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") GT 0.05)
+ (SUM(CLS$(1$lndmatfrfr(landtype,cls)*sum((owner,site,spec)
         ,whentran(regs,cls,site,owner,spec,"toag")) gt 0 ),
      - SUM(DECSP$(ORD(DECSP) LE ORD(DEC)),
            SUM(THREE,LANDTOAG(REGS,CLS,DECSP,THREE)
                    $YESCONLND(REGS,CLS,three))))
+ SUM(CLS$( 1$lndmattofr(landtype,cls)*
       sum((site,spec),whentran(regs,cls,site,"op",spec,"fromag") )),
       SUM(DECSP$(ORD(DECSP) LE ORD(DEC)),LANDFROMAG(REGS,CLS,DECSP))))
       $yesfor
   =L= 0. ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
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*   AGRICULTURAL LAND CONVEXITY

 CLAND(DEC,REGS,LANDTYPE)$(YESAG GT 0 AND SEPAG GT 0 AND
                          NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") GT 0.05 )..
        SUM(STEPS,LANDSUPPLS(DEC,REGS,LANDTYPE,STEPS) ) =L= 1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL WATER BALANCE BY REGION

 WATERR(DEC,REGS)$(NEWWATSUP(REGS,"FIXEDMAX")+NEWWATSUP(REGS,"PUMPQ")+
                 NEWWATSUP(REGS,"PUMPMAX") GT 0 AND YESAG GT 0)..
         (SUM((CROP,TECH)$FARMPROD("SLIPPAGE",CROP),
                 CROPBUDGET(DEC,REGS,CROP,"IRRIG","PARTICIP",TECH)
                *SCALPROD
                *NEWBUDDATA("WATER",REGS,CROP,"IRRIG","PARTICIP",TECH)
                *AGQDYN("WATER",DEC)+
                 CROPBUDGET(DEC,REGS,CROP,"IRRIG","NONPART",TECH)
                *SCALPROD
                *NEWBUDDATA("WATER",REGS,CROP,"IRRIG","NONPART",TECH)   )
                *AGQDYN("WATER",DEC) +
             SUM((CROP,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                 CROPBUDGET(DEC,REGS,CROP,"IRRIG","BASE",TECH)
                *SCALPROD
                *NEWBUDDATA("WATER",REGS,CROP,"IRRIG","BASE",TECH)
                *AGQDYN("WATER",DEC)      ) +
             SUM((ANIMAL,LIVETECH),
                 LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)
                *SCALLIVE
                *NEWLIVEBUD("WATER",REGS,ANIMAL,LIVETECH)
                *AGQDYN("WATER",DEC)))/SCALE("WATER")
          - WATERFIX(DEC,REGS)
          - WATERVAR(DEC,REGS)$(SEPAG LE 0 OR
              NEWWATSUP(REGS,"PUMPELAS")   LE 0.05 )
          -  SUM(STEPS,
     (NEWWATSUP(REGS,"PUMPQ")*WATERGRW(REGS,DEC)*QINC(STEPS))
        *WATERVARS(DEC,REGS,STEPS))$(SEPAG GT 0 AND
               NEWWATSUP(REGS,"PUMPELAS")   GT 0.05)/SCALE("WATER")
          =L= 0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL WATER CONVEXITY

 CWATERR(DEC,REGS)$(NEWWATSUP(REGS,"FIXEDMAX")+NEWWATSUP(REGS,"PUMPQ")+
                 NEWWATSUP(REGS,"PUMPMAX") GT 0 AND YESAG GT 0 AND
                  NEWWATSUP(REGS,"PUMPQ") GT 0 AND SEPAG GT 0)..
            SUM(STEPS, WATERVARS(DEC,REGS,STEPS))    =L= 1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL FIXED PRICE WATER MAXIMUM

 FIX(DEC,REGS)$(YESAG GT 0 AND NEWWATSUP(REGS,"FIXEDMAX"))..
          WATERFIX(DEC,REGS)
          =L= NEWWATSUP(REGS,"FIXEDMAX")*WATERGRW(REGS,DEC)
            /SCALE("WATER");

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL AUMS BALANCE BY REGION

 AUMSR(DEC,REG)$(YESAG GT 0 AND
  NEWAUMSSUP(REG,"PUBLICMAX")+NEWAUMSSUP(REG,"PRIVATEQ") GT 0)..

    SUM((ANIMAL,LIVETECH),
         LVSTBUDGET(DEC,REG,ANIMAL,LIVETECH)
       * SCALLIVE
       * NEWLIVEBUD("AUMS",REG,ANIMAL,LIVETECH)) /SCALE("AUMS")
  - AUMSPUB(DEC,REG)$ (NEWAUMSSUP(REG,"PUBLICMAX") GT .1)
  - AUMSPRIV(DEC,REG)$(SEPAG LE 0 OR NEWAUMSSUP(REG,"PRIVATELAS") LE 0.05 )
  - SUM(STEPS,
        NEWAUMSSUP(REG,"PRIVATEQ")*QINC(STEPS)*AUMSPRIVS(DEC,REG,STEPS))
        $(SEPAG GT 0  AND NEWAUMSSUP(REG,"PRIVATELAS") GT 0.05 )/SCALE("AUMS")
  =L= 0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL AUMS CONVEXITY

 CAUMSR(DEC,REGS)$(    YESAG GT 0 AND SEPAG GT 0
                   AND NEWAUMSSUP(REGS,"PRIVATELAS")   GT 0.05)..
        SUM(STEPS, AUMSPRIVS(DEC,REGS,STEPS))    =L= 1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL PUBLIC AUMS MAXIMUM

 PUBAUMS(DEC,REG)$ (NEWAUMSSUP(REG,"PUBLICMAX") GT 0 AND YESAG GT 0)..
      AUMSPUB(DEC,REG)
  =L=
      NEWAUMSSUP(REG,"PUBLICMAX")/SCALE("AUMS");

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL LABOR BALANCE BY REGION

 LABOR(DEC,REGS)$((newlabsupP(REGS,"FAMILYPRC") gt 0 or
      NEWLABSUPP(REGS,"HIREQ") GT 0) AND YESAG GT 0)..
      (SUM((CROP,WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
             CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH) * SCALPROD
           * NEWBUDDATA("LABOR",REGS,CROP,WTECH,"PARTICIP",TECH)
           * AGQDYN("LABOR",DEC)
           + CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)*SCALPROD
                 *NEWBUDDATA("LABOR",REGS,CROP,WTECH,"NONPART",TECH)
                 *AGQDYN("LABOR",DEC)  )
           + SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)    *SCALPROD
                 *NEWBUDDATA("LABOR",REGS,CROP,WTECH,"BASE",TECH)
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                 *AGQDYN("LABOR",DEC)     )
           + SUM((ANIMAL,LIVETECH),
                  LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH) *SCALLIVE
                 *NEWLIVEBUD("LABOR",REGS,ANIMAL,LIVETECH)
                 *AGQDYN("LABOR",DEC)))/SCALE("LABOR")
      - FAMILY(DEC,REGS)$ NEWLABSUPP(REGS,"FAMILYPRC")
      - HIRED(DEC,REGS)$(NEWLABSUPP(REGS,"HIREQ") GT 0 AND
                       (SEPAG LE 0 OR NEWLABSUPP(REGS,"HIREELAS") LE 0.05))
      - SUM(STEPS,
            NEWLABSUPP(REGS,"HIREQ")*LABORGRW(REGS,DEC)*QINC(STEPS)*
            HIREDS(DEC,REGS,STEPS) )
            $(SEPAG GT 0 AND NEWLABSUPP(REGS,"HIREELAS") GT 0.05)
           /SCALE("LABOR")

     =L= 0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL LABOR CONVEXITY

    CLABOR(DEC,REGS)$(YESAG GT 0 AND SEPAG GT 0
                 AND NEWLABSUPP(REGS,"HIREELAS") GT 0.05)..
       SUM(STEPS, HIREDS(DEC,REGS,STEPS) )   =L= 1;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL FAMILY MAXIMUM

   FAMILYLIM(DEC,REGS)$(yesag gt 0 and
   NEWLABSUPP(REGS,"FAMILYprc")*newlabsupp(regs,"familymax") GT 0 )..
          FAMILY(DEC,REGS) =L= NEWLABSUPP(REGS,"FAMILYMAX")
           *LABORGRW(REGS,DEC)/SCALE("LABOR") ;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL HIRED LABOR MAXIMUM

   HIRELIM(DEC,REGS)$(NEWLABSUPP(REGS,"HIREMAX") GT 0 AND YESAG GT 0)..
        HIRED(DEC,REGS)$(SEPAG LE 0 OR NEWLABSUPP(REGS,"HIREELAS") LE 0.05)
      + SUM(STEPS,
          NEWLABSUPP(REGS,"HIREQ")*LABORGRW(REGS,DEC)*QINC(STEPS)*
          HIREDS(DEC,REGS,STEPS) )
             $(SEPAG GT 0 AND NEWLABSUPP(REGS,"HIREELAS") GT 0.05)
         /SCALE("LABOR")
        =L=
        NEWLABSUPP(REGS,"HIREMAX") *LABORGRW(REGS,DEC)/SCALE("LABOR") ;


*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL CROP MIX BALANCE BY CROP AND REGION

 MIXREG(DEC,CROP,REGS)$(SUM(CRPMIXALT,NEWMIXDATA(CROP,REGS,CRPMIXALT)) GT 0
                       AND YESAG GT 0 AND CROPMIXY(DEC) GT 0)..
           SUM((WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
                *SCALPROD/SCALMIX
                *(NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"PARTICIP",TECH)
                 -NEWBUDDATA("ADDLAND",REGS,CROP,WTECH,"PARTICIP",TECH))
               + CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
                *SCALPROD/SCALMIX
                *NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"NONPART",TECH)  )
          +SUM((WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                *SCALPROD/SCALMIX
                *NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"BASE",TECH)     )
          -SUM(CRPMIXALT
              ,NEWMIXDATA(CROP,REGS,CRPMIXALT)*MIXR(DEC,REGS,CRPMIXALT))
           /SCALMIX
          + TWID(DEC,CROP,REGS)
          =E= 0.0;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL CROP MIX BALANCE TOTAL LAND USE BY REGION

 MIXREGTOT(DEC,REGS)
         $(SUM(CRPMIXALT,SUM(CROP,NEWMIXDATA(CROP,REGS,CRPMIXALT))) GT 0
        AND YESAG GT 0 AND CROPMIXY(DEC) GT 0)..
           SUM((CROP,WTECH,TECH)$FARMPROD("SLIPPAGE",CROP),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
                *SCALPROD/SCALMIX
                *(NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"PARTICIP",TECH)
                 -NEWBUDDATA("ADDLAND",REGS,CROP,WTECH,"PARTICIP",TECH))
               +  CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
                *SCALPROD/SCALMIX
                *NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"NONPART",TECH)  )
           +SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                *SCALPROD/SCALMIX
                *NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"BASE",TECH)     )
         - SUM(CRPMIXALT,SUM(CROP,
               NEWMIXDATA(CROP,REGS,CRPMIXALT))*MIXR(DEC,REGS,CRPMIXALT))
           /SCALMIX
        =E= 0.;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   AGRICULTURAL LIVESTOCK NATIOANAL MIX BALANCE BY COMMODITY AND REGION

 MIXNAT(DEC,PRIMARY,REGS)
            $(SUM(NATMIXALT,NEWNATMIXD(REGS,PRIMARY,NATMIXALT)) GT 0 AND
             YESAG GT 0 AND CROPMIXY(DEC) GT 0)..
            SUM((CROP,WTECH,TECH)
               $(FARMPROD("SLIPPAGE",CROP)
                *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"PARTICIP",TECH)),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"PARTICIP",TECH)
                *SCALPROD/SCALMIX
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                *(NEWBUDDATA("CROPLAND",REGS,CROP,WTECH,"PARTICIP",TECH)
                 -NEWBUDDATA("ADDLAND",REGS,CROP,WTECH,"PARTICIP",TECH))
              +   CROPBUDGET(DEC,REGS,CROP,WTECH,"NONPART",TECH)
                *SCALPROD/SCALMIX
                *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"NONPART",TECH)  )
           +SUM((CROP,WTECH,TECH)$(FARMPROD("SLIPPAGE",CROP) LE 0.0 AND
                NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"NONPART",TECH) GT 0),
                 CROPBUDGET(DEC,REGS,CROP,WTECH,"BASE",TECH)
                *SCALPROD/SCALMIX
                *NEWBUDDATA(PRIMARY,REGS,CROP,WTECH,"BASE",TECH)     )
           +SUM((ANIMAL,LIVETECH)$NEWLIVEBUD(PRIMARY,REGS,ANIMAL,LIVETECH),
               LVSTBUDGET(DEC,REGS,ANIMAL,LIVETECH)
               *SCALLIVE/SCALMIX
               *NEWLIVEBUD(PRIMARY,REGS,ANIMAL,LIVETECH))
         - SUM(NATMIXALT,
               NEWNATMIXD(REGS,PRIMARY,NATMIXALT)*NATMIX(DEC,PRIMARY,NATMIXALT))
            /SCALMIX
         + TOLR(DEC,PRIMARY,REGS) =E= 0.;

*   &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&
*   CARBON BALANCE

 CARBON(DEC)..
* CARBON FROM AN INITIAL STAND PREHARVEST
     (SCFOR*(
     (SUM(WHEN$(TODAY+ELAPSED(WHEN) GT DATE(DEC)),
       (SUM((REGS,CLS,OWNER,SITE,COHORT,MIC,SPECIES)
            $ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
*TREE CARBON
         (SUM(SPEC$SPMAPPR(SPECIES,SPEC),
            SUM(TIME2$(10*(ORD(TIME2)-1)+TODAY EQ DATE(DEC)),
              SUM(PRODS$YESITIS(REGS,PRODS),
                EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,TIME2)))
              * TREECARB(REGS,"TREECRBYLD",SPEC) )
*ECOSYSTEM CARBON
         +SUM(SPEC$SPMAPPR(SPECIES,SPEC),
            SUM(COHORTS$AGING(COHORT,DEC,COHORTS),
              SUM(ECOCARBTYP,
                 ECOSYSCARB(REGS,COHORTS,SPEC,"FORONLY",ECOCARBTYP)))))
              *  EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN))))
* CARBON FROM AN INITIAL STAND AT AND AFTER HARVEST
 + SUM(WHEN$(TODAY+ELAPSED(WHEN) LE DATE(DEC)),
     SUM((REGS,CLS,OWNER,SITE,COHORT,MIC,SPECIES)
         $ISEXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN),
* HARVESTED WOOD CARBON AND RESIDUE CARBON
     + SUM(TIME$AGESINCE(WHEN,DEC,TIME) ,
         SUM(SPEC$SPMAPPR(SPECIES,SPEC),
           SUM(PRODS$YESITIS(REGS,PRODS)
             , EXISTYLD(PRODS,REGS,CLS,OWNER,SPECIES,COHORT,SITE,MIC,WHEN)
            * (TREECARB(REGS,"CARBONFAC",SPEC)
            * (CARBFATE(REGS,PRODS,"INPRODUCT",TIME)
            +  CARBFATE(REGS,PRODS,"BURNDISPL",TIME)*INCLDISPL)
            + TREECARB(REGS,"NONMRCCARB",SPEC)*RESCARBFAT(REGS,SPEC,TIME)
            * RESIDUEFR("INRESIDUE",REGS,PRODS))  ) ) )
            * EXIST(REGS,CLS,OWNER,SPECIES,SITE,COHORT,MIC,WHEN)))
* CARBON FROM A REESTABLISHED STAND PREHARVEST
     + SUM(DECSP$(DATE(DECSP) LE DATE(DEC)),
         SUM(WHEN$(DATE(DECSP)+ELAPSED(WHEN) GT DATE(DEC)
             AND WHENDONE(DECSP,WHEN) GT 0),
           SUM((REGS,CLS,OWNER,SITE,SPECIES,MIC,policy)$(
             ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
             and examine(policy) gt 0),
*TREE CARBON
              (SUM(SPEC$SPMAPPR(SPECIES,SPEC),
                 SUM(TIME2$(ORD(DECSP)+ORD(TIME2)-1 EQ ORD(DEC)),
                   SUM(PRODS$YESITIS(REGS,PRODS)
                    ,NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,TIME2)))
                   * TREECARB(REGS,"TREECRBYLD",SPEC) )
*ECOSYSTEM CARBON
              +SUM(SPEC$SPMAPPR(SPECIES,SPEC),
                 SUM(COHORTS$AGINGNEW(DECSP,DEC,COHORTS),
                   SUM(ECOCARBTYP,
                     ECOSYSCARB(REGS,COHORTS,SPEC,"FORONLY",ECOCARBTYP)))))
                   * NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECSP,policy)*
                     yespolicy(policy,cls,owner,species,site,mic)
                   * policyinc(policy,decsp,"exist"))))
*  CARBON FROM A REESTABLISHED STAND AT AND POSTHARVEST
     + SUM(DECSP$(DATE(DECSP) LE DATE(DEC)),
          SUM(WHEN$(DATE(DECSP)+ELAPSED(WHEN) LE DATE(DEC)
               AND WHENDONE(DECSP,WHEN) GT 0),
             SUM((REGS,CLS,OWNER,SITE,SPECIES,MIC,policy)$
                 (ISNEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN) gt 0
                  and examine(policy) gt 0),
* HARVESTED WOOD CARBON AND RESIDUE CARBON
               + SUM(TIME2$(ORD(DECSP)+ORD(WHEN)-1+ORD(TIME2)-1 EQ ORD(DEC)),
                    SUM(SPEC$SPMAPPR(SPECIES,SPEC),
                      SUM(PRODS$YESITIS(REGS,PRODS)
                       ,NEWYLD(PRODS,REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN )
                     *  (TREECARB(REGS,"CARBONFAC",SPEC)
                     *  (CARBFATE(REGS,PRODS,"INPRODUCT",TIME2)
                     +  CARBFATE(REGS,PRODS,"BURNDISPL",TIME2)*INCLDISPL)
                     +  TREECARB(REGS,"NONMRCCARB",SPEC)*
                        RESCARBFAT(REGS,SPEC,TIME2)
                     *  RESIDUEFR("INRESIDUE",REGS,PRODS)))))
                     *  NEW(REGS,CLS,OWNER,SPECIES,SITE,MIC,WHEN,DECSP,policy)*
                        yespolicy(policy,cls,owner,species,site,mic)
                     *  policyinc(policy,decsp,"exist"))))
*   CARBON FROM A STAND COMING FROM AGRICUTURE
   + SUM(DECSP$(ORD(DECSP) LE ORD(DEC)),
       SUM((REG,cls,SPEC)
      $sum((site,owner),whentran(reg,cls,site,owner,spec,"fromag")),
         SUM(COHORT$(ORD(DECSP)+ORD(COHORT)-1 EQ ORD(DEC)),
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           SUM(ECOCARBTYP,ECOSYSCARB(REG,COHORT,SPEC,CLS,ECOCARBTYP)))*
                  CONVRTFRAG(REG,CLS,DECSP,SPEC)
               $( SUM(lndmattofr(LANDTYPE,CLS),1) gt 0
        and      SUM((SPMAPPR(SPECIES,SPEC),site,MIC,WHEN2),
                  ISNEW(REG,CLS,"OP",SPECIES,site,MIC,WHEN2)) gt 0)
          ))$(YESFOR*YESAG)))
   +sum((regs,landtype),
         LANDSUPPLY(DEC,REGs,LANDTYPE)*agsoilcarb(regs,landtype)) $yesag
  )   /2204
     =E=
   CARBONSE(DEC)  ;

*FORESTRY BOUNDS

* LIMITS ON CAPACITY BUILDING MAXIMUM CHANGES #####################*

   BUILDCAP.UP("SAWTSW",DEC)$(CAPACITY("SAWTSW","NOWINPLACE") GT 0
                                   AND YESFOR GT 0) = 800/SCFOR;
   BUILDCAP.UP("PULPSW",DEC)$(YESFOR GT 0
                      AND (CAPACITY("PULPSW","NOWINPLACE") GT 0)) = 20.0/SCFOR;
   BUILDCAP.UP("PULPHW",DEC)$(YESFOR GT 0
             AND (CAPACITY("PULPHW","NOWINPLACE") GT 0)) = 10.0/SCFOR;

*LIMIT ON FOREST PRODUCTS TRADE
   TRADEQUAN.LO(TRADEREG,PRODS,DEC,TRADE)$(
         TRADFOR(TRADEREG,TRADE,PRODS,DEC,"MINQ") GT 0
                               AND YESFOR GT 0)=
         TRADFOR(TRADEREG,TRADE,PRODS,DEC,"MINQ")/SCFOR;
   TRADEQUAN.UP(TRADEREG,PRODS,DEC,TRADE)$(
         TRADFOR(TRADEREG,TRADE,PRODS,DEC,"MAXQ") GT 0
                               AND YESFOR GT 0)=
         TRADFOR(TRADEREG,TRADE,PRODS,DEC,"MAXQ")/SCFOR;

 DEMANDFOR.LO(PRODS,DEC)
             $(FPDEMAND(PRODS,DEC,"MINQ") GT 0
                                    AND YESFOR GT 0
            AND (SEPFOR EQ 0 OR FPDEMAND(PRODS,DEC,"SLOPE") EQ 0)) =
                    FPDEMAND(PRODS,DEC,"MINQ")/SCFOR;
 DEMANDFOR.UP(PRODS,DEC) $(FPDEMAND(PRODS,DEC,"MAXQ") GT 0
                               AND YESFOR GT 0
            AND (SEPFOR EQ 0 OR FPDEMAND(PRODS,DEC,"SLOPE") EQ 0)) =
                    FPDEMAND(PRODS,DEC,"MAXQ")/SCFOR;

*AGRICULTURAL BOUNDS
 TWID.LO(DEC,CROP,REGS)$(SUM(CRPMIXALT,NEWMIXDATA(CROP,REGS,CRPMIXALT)) GT 0
                         AND YESAG GT 0 AND CROPMIXY(DEC) GT 0)
         = -0.001*NEWMIXDATA(CROP,REGS,"1989")/SCALMIX;

 TWID.UP(DEC,CROP,REGS)$(SUM(CRPMIXALT,NEWMIXDATA(CROP,REGS,CRPMIXALT)) GT 0
                         AND YESAG GT 0 AND CROPMIXY(DEC) GT 0)
               = 0.001*NEWMIXDATA(CROP,REGS,"1989")/SCALMIX;

 TOLR.LO(DEC,PRIMARY,REGS)
        $(SUM(NATMIXALT,NEWNATMIXD(REGS,PRIMARY,NATMIXALT)) GT 0
                         AND YESAG GT 0 AND CROPMIXY(DEC) GT 0)
               = -0.001*NEWNATMIXD(REGS,PRIMARY,"1986")/SCALMIX;

 TOLR.UP(DEC,PRIMARY,REGS)
         $(SUM(NATMIXALT,NEWNATMIXD(REGS,PRIMARY,NATMIXALT))  GT 0
                         AND YESAG GT 0 AND CROPMIXY(DEC) GT 0)
              =  0.001*NEWNATMIXD(REGS,PRIMARY,"1986")/SCALMIX ;

 IMPORTP.UP(DEC,PRIMARY)$(SEPAG LE 0 AND PIMPORT(PRIMARY,"MAXQ") GT 0
                         AND YESAG GT 0 )
              = PIMPORT(PRIMARY,"MAXQ")*IMPORTGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
 IMPORTP.LO(DEC,PRIMARY)$(SEPAG LE 0 AND (PIMPORT(PRIMARY,"MINQ") GT 0 OR
                       PIMPORT(PRIMARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = MAX(1.,PIMPORT(PRIMARY,"MINQ")*IMPORTGRW(PRIMARY,DEC)  )
              /SCALE(PRIMARY)        ;
 EXPORTP.UP(DEC,PRIMARY)
    $(SEPAG LE 0 AND PEXPORT(PRIMARY,"MAXQ") GT 0  AND YESAG GT 0)
              = PEXPORT(PRIMARY,"MAXQ")*EXPORTGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
 EXPORTP.LO(DEC,PRIMARY)$(SEPAG LE 0 AND (PEXPORT(PRIMARY,"MINQ") GT 0 OR
                      PEXPORT(PRIMARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = MAX(1.,PEXPORT(PRIMARY,"MINQ"))*EXPORTGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
 DEMANDP.UP(DEC,PRIMARY)
      $(SEPAG LE 0 AND PDEMAND(PRIMARY,"MAXQ") GT 0
                      AND YESAG GT 0)
              = PDEMAND(PRIMARY,"MAXQ")*DEMANDGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
DEMANDP.LO(DEC,PRIMARY)$((SEPAG LE 0 AND PDEMAND(PRIMARY,"MINQ") GT 0 OR
                     PDEMAND(PRIMARY,"ELASTICITY") GT 0)
                        AND YESAG GT 0)
             = MAX(1.,PDEMAND(PRIMARY,"MINQ")*DEMANDGRW(PRIMARY,DEC))
             /SCALE(PRIMARY)        ;
 IMPORTS.UP(DEC,SECONDARY)$(SEPAG LE 0 AND SIMPORT(SECONDARY,"MAXQ") GT 0
                         AND YESAG GT 0)
              = SIMPORT(SECONDARY,"MAXQ")*IMPORTGRW(SECONDARY,DEC)
                /SCALE(SECONDARY);
 IMPORTS.LO(DEC,SECONDARY)$(SEPAG LE 0 AND (SIMPORT(SECONDARY,"MINQ") GT 0 OR
                      SIMPORT(SECONDARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = MAX(1.,SIMPORT(SECONDARY,"MINQ")*IMPORTGRW(SECONDARY,DEC))
                /SCALE(SECONDARY);
 EXPORTS.UP(DEC,SECONDARY)
  $(SEPAG EQ 0 AND SEXPORT(SECONDARY,"MAXQ") GT 0
                         AND YESAG GT 0)
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              = SEXPORT(SECONDARY,"MAXQ")*EXPORTGRW(SECONDARY,DEC)
                /SCALE(SECONDARY);
 EXPORTS.LO(DEC,SECONDARY)$(SEPAG EQ 0 AND (SEXPORT(SECONDARY,"MINQ") GT 0 OR
                      SEXPORT(SECONDARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = MAX(1.,SEXPORT(SECONDARY,"MINQ")*EXPORTGRW(SECONDARY,DEC))
                /SCALE(SECONDARY);
 DEMANDS.UP(DEC,SECONDARY)
     $(SDEMAND(SECONDARY,"MAXQ") GT 0
                       AND SEPAG EQ 0 AND YESAG GT 0)
              = SDEMAND(SECONDARY,"MAXQ")*DEMANDGRW(SECONDARY,DEC)
                /SCALE(SECONDARY);
 DEMANDS.LO(DEC,SECONDARY)$((SDEMAND(SECONDARY,"MINQ") GT 0 OR
                      SDEMAND(SECONDARY,"ELASTICITY") GT 0)
                         AND SEPAG EQ 0 AND YESAG GT 0)
              = MAX(1.,SDEMAND(SECONDARY,"MINQ")*DEMANDGRW(SECONDARY,DEC))
                /SCALE(SECONDARY);

 LANDSUPPLY.LO(DEC,REGS,LANDTYPE)$(SEPAG LE 0
             AND NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") GT 0
                         AND YESAG GT 0) = 1.
            /SCALE(LANDTYPE);
 WATERVAR.LO(DEC,REGS)$(SEPAG LE 0 AND NEWWATSUP(REGS,"PUMPELAS")  GT 0
                         AND YESAG GT 0)      = 1.
            /SCALE("WATER") ;
 AUMSPRIV.LO(DEC,REG)$(SEPAG LE 0 AND NEWAUMSSUP(REG,"PRIVATELAS") NE 0) =1.
            /SCALE("AUMS") ;
 HIRED.LO(DEC,REGS) $(SEPAG LE 0 OR NEWLABSUPP(REGS,"HIREELAS")   GT 0
                         AND YESAG GT 0)                   = 1.
            /SCALE("LABOR") ;

 CROPBUDGET.LO(DEC,REGS,CROP,WTECH,CTECH,TECH)
              $(NEWBUDDATA("MINIMUM",REGS,CROP,WTECH,CTECH,TECH)  GT 0
                         AND YESAG GT 0)  =
               NEWBUDDATA("MINIMUM",REGS,CROP,WTECH,CTECH,TECH)/SCALPROD ;

 CROPBUDGET.UP(DEC,REGS,CROP,WTECH,CTECH,TECH)
               $(NEWBUDDATA("MAXIMUM",REGS,CROP,WTECH,CTECH,TECH)  GT 0
                         AND YESAG GT 0) =
                 NEWBUDDATA("MAXIMUM",REGS,CROP,WTECH,CTECH,TECH)/SCALPROD ;

 LVSTBUDGET.LO(DEC,REGS,ANIMAL,LIVETECH)
       $ (NEWLIVEBUD("MINIMUM",REGS,ANIMAL,LIVETECH)  GT 0
                         AND YESAG GT 0)
       = NEWLIVEBUD("MINIMUM",REGS,ANIMAL,LIVETECH) ;
 LVSTBUDGET.UP(DEC,REGS,ANIMAL,LIVETECH)
       $( NEWLIVEBUD("MAXIMUM",REGS,ANIMAL,LIVETECH)  GT 0
                         AND YESAG GT 0)
       = NEWLIVEBUD("MAXIMUM",REGS,ANIMAL,LIVETECH)/SCALLIVE ;
 PROCESS.LO(DEC,PROCESSALT)$(PROCBUD("MINIMUM",PROCESSALT)  GT 0
                         AND YESAG GT 0)
                       =PROCBUD("MINIMUM",PROCESSALT)/SCALPROC;

 PROCESS.UP(DEC,PROCESSALT)
   $(PROCBUD("MAXIMUM",PROCESSALT)  GT 0
                          AND YESAG GT 0)
                       =PROCBUD("MAXIMUM",PROCESSALT)/SCALPROC;

* INITIAL VALUES FOR NONLINEAR VARIABLES

 IMPORTP.L(DEC,PRIMARY)$(SEPAG LE 0 AND (PIMPORT(PRIMARY,"QUANTITY") GT 0 OR
                      PIMPORT(PRIMARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = PIMPORT(PRIMARY,"QUANTITY")*IMPORTGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
 EXPORTP.L(DEC,PRIMARY)$(SEPAG LE 0 AND (PEXPORT(PRIMARY,"QUANTITY") GT 0 OR
                      PEXPORT(PRIMARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = PEXPORT(PRIMARY,"QUANTITY")*EXPORTGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
 DEMANDP.L(DEC,PRIMARY)$((PDEMAND(PRIMARY,"QUANTITY") GT 0 OR
                      PDEMAND(PRIMARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0 AND SEPAG LE 0)
              = PDEMAND(PRIMARY,"QUANTITY")*DEMANDGRW(PRIMARY,DEC)
              /SCALE(PRIMARY)        ;
 IMPORTS.L(DEC,SECONDARY)$(SEPAG LE 0 AND (SIMPORT(SECONDARY,"QUANTITY") GT 0 OR
                      SIMPORT(SECONDARY,"ELASTICITY") GT 0)
                         AND YESAG GT 0)
              = SIMPORT(SECONDARY,"QUANTITY")*IMPORTGRW(SECONDARY,DEC)
                /SCALE(SECONDARY);
 EXPORTS.L(DEC,SECONDARY)$((SEXPORT(SECONDARY,"QUANTITY") GT 0 OR
                      SEXPORT(SECONDARY,"ELASTICITY") GT 0)
                         AND SEPAG EQ 0 AND YESAG GT 0)
              = SEXPORT(SECONDARY,"QUANTITY")*EXPORTGRW(SECONDARY,DEC)
                /SCALE(SECONDARY);
 DEMANDS.L(DEC,SECONDARY)$((SDEMAND(SECONDARY,"QUANTITY") GT 0 OR
                      SDEMAND(SECONDARY,"ELASTICITY") GT 0)
                         AND SEPAG EQ 0 AND YESAG GT 0)
              = SDEMAND(SECONDARY,"QUANTITY")*DEMANDGRW(SECONDARY,DEC)
                /SCALE(SECONDARY);
 LANDSUPPLY.L(DEC,REGS,LANDTYPE)$(SEPAG LE 0 AND
                NEWLNDSUPP(LANDTYPE,REGS,"ELASTICITY") GT 0
                         AND YESAG GT 0)
         = NEWLNDSUPP(LANDTYPE,REGS,"QUANTITY")*AGLANDGRW(REGS,LANDTYPE,DEC)
            /SCALE(LANDTYPE)  ;
 WATERVAR.L(DEC,REGS)$(SEPAG LE 0 AND NEWWATSUP(REGS,"PUMPELAS") GT 0.
                         AND YESAG GT 0)
              = NEWWATSUP(REGS,"PUMPQ")*WATERGRW(REGS,DEC)
                   /SCALE("WATER") ;
 AUMSPRIV.L(DEC,REG)$(SEPAG LE 0 AND NEWAUMSSUP(REG,"PRIVATELAS") GT 0)
              = NEWAUMSSUP(REG,"PRIVATEQ")/SCALE("AUMS") ;
 HIRED.L(DEC,REGS) $(SEPAG LE 0 AND NEWLABSUPP(REGS,"HIREELAS")  GT 0
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```
                         AND YESAG GT 0)
              = NEWLABSUPP(REGS,"HIREQ")*LABORGRW(REGS,DEC)
               /SCALE("LABOR") ;

OPTION LIMROW=0;
OPTION LIMCOL=0;
OPTION ITERLIM=1000000;
OPTION RESLIM=250000;
 MODEL AGFOR / ALL /;
 AGFOR.OPTFILE = 1;
*$include "fabasis.put"
*option nlp=blockpict;
SOLVE AGFOR USING NLP MAXIMIZING WELFARE;
```

APPENDIX D

FASOM FILE STRUCTURE

This appendix details the structure and sequence of the files that make up the FASOM model. FASOM is implemented in the GAMS algebraic modeling language. The model is decomposed into a number of files. This is done to allow separation of distinctly different types of data and to allow disciplinary experts to work on selected parts of the model. Functionally the program can be divided several ways. The division we will describe separates out files into categories according to whether they involve data, data calculations, model specification, analysis execution and report writing. Distinctions will also be made between unifying files, forestry files, agricultural files and carbon files.

D1.0 FILE STRUCTURE

Table D-1 gives an alphabetic list of each of the FASOM files.

Table D-1. Description of the Files Within FASOM

Filename	Description
ALLOFIT	Unifies the presolution files in FASOM using a set of include statements. This is used to limit the number of job steps in a GAMS run.
ALLOFIT.SML	Small model version of ALLOFIT
CAP.PRN	Forest processing capacities.
EST.PRN	Forest establishment costs.
EXIST.PRN	Yield tables for existing forest crops (reformatted into EXIST.PUT)
EXIST.PUT	Contains reformat of existing yield files including residues and biomass
EXIST.PUT	Reformats NEW.PRN and EXIST.PRN into NEW.PUT EXIST.PUT and INV.PUT
FAAGDAT.SML	Small data set version of FAAGDAT.PUT
FABAS	Invokes GAMSBAS to save a basis
FABAS.BAS	Saved basis
FAAGDAT.PUT	Agricultural data for the full ASM version.
FAAGDYN	Data on dynamic trends in agriculture.
FAALTRUN	Contains instructions which cause a alternative runs to be executed. At this point the runs are the SIPS forest subsidy and a change in public harvest cut scenarios.
FAAGWEL	Agricultural welfare report writing calculations

FAASMCAL	Contains the calculations done in the setting up the agricultural sector model.
FAASMRPT	Contains instructions which do the reporting on the agricultural sector model part of the overall model.
FABASRUN	Run of Base model
FACARBON	Contains the raw input data on carbon.
BIOMASS.PRN	Data for biofuels analysis including milling resides.
CEA	Economic advisors forestry demand scenario
DEF	Guess at deficiency payment
EXISTBIO.PRN	Yields of existing trees harvested for biomass (reformatted into EXIST.PUT)
EXISTLOG.PRN (reformatted	Logging residue yields of existing trees harvested with logging residues gathered into EXIST.PUT)
FACOMPAR	Saves data for the comparative report writer. Picks up data from the forestry, carbon and the agricultural report writers for a cross-run comparison.
FACRBRPT	Carbon report writer.
FAFINAL	Summary report writer for a comparative run.
FAFORDAT	Integrates the forestry data files
FAFORDAT.SML	Small version of a FAFORDAT for debugging proposes.
FAFORLOT	Saves forestry data in Lotus importable form
FAFORLOT.PUT	Lotus importable forestry data
FAFORRPT	Forestry report writer.
FAFORWEL	Forestry welfare report writers calculations
FAMODEL	Unifying equations describing the whole model.
FAMODSET	Miscellaneous model setup data including the separable programming step specification.
FAPOLDAT	Data used in setting up the policy scenarios in the alternative runs.
FARPT	Parameter statements for the report writing routines.
FASETS	Definitions of the sets which are shared between all the subsectors.

FASETS.SML	Version of FASETS for small model
FASOLVFP	Solves model including attaing farm program convergence
FAUPDATE	Updates forestry ISNEW and ISEXIST data to indicate what policy alternatives are being examined
FPDMD.PRN	Forest product demand equation data.
GROW.PRN	Forest maintenance costs for growing stock.
INTER.PRN	Forest product transportation cost data.
INV.PRN	Forest inventory.
INV.PUT	Reformat of INV.PRN
MINOS5.OPT	Option file for use with MINOS.NLP Solver.
MINHARV.RES	Alternative minimum harvest age data
NEWBIO.PRN	Biomass data for new stands (reformatted into NEW.PUT)
NEWLOG.PRN	Logging residue for new stands (reformatted into NEW.PUT)
NEW.PRN	Contains yield tables for reforestation activities (reformatted into new.but)
NEW.PUT	Reformat of NEW.PRN including biomass and logging residues
PUBLIC.PRN	Public cut for base model
PUB195.PRN	Low scenario public cut date
PUB198.PRN	High scenario public cut data
ROTATE.PRN	Rotation Age data
.RECYCLE	Recycling scenario data
TRADEDMD.PRN	Forest international trade export and import data.

These files may also be classified in terms of their function and aim. A listing of the files, along those lines, is given below in Table D-2.

Table D-2. File Structure and Functions in FASOM

Sector or Function	Data	Data Calculation	Model Specification	Solution Analysis	Report Writing
Forest Sector	CAP.PRN EXIST,PUT EST.PRN EXIST.PRN EXIST.PUT FAFORDAT FAFORDAT.SML FPDMD.PRN GROW.PRN INTER.PRN INV.PRN INV.PUT NEW.PRN NEW.PUT PUBLIC.PRN ROTATE.PRN TRADEDMD.PRN	EXISTPUT			FAFORRPT FAFORLOT FAFORWEL FAFORLOT.PUT
Agricultural Sector	FAAGDAT FAAGDAT.PUT FAAGDYN DEF	FAASMCAL			FAASMRPT FAAGWEL
Carbon Sector	FACARBON				FACRBRPT
Unifying	ALLOFIT FAMODSET FASETS		FAMODEL	FABASRUN FASOLVFP	FACOMPAR FAFINAL FARPT
Policy Analysis	FAPOLDAT BIOMASS.PRN CEA PUB195.PRN PUB198.PRN MINHARV.RES RECYCLE	FAUPDATE		FAAGTREE FAALTRUN FACARRUN	
Computer files	EXISTPUT FABAS.BAS			MINOS5.OPT A.BAT Y	

Small Model Files	FAAGDAT.SML FASETS.SML ALLOFIT.SML FAFORDAT.SML

D2.0 BATCH FILE SEQUENCE AND CONTROL SWITCHES

The basic method is to run five files in sequence using a batch file, (Prefix).BAT. The files run are in the order given below, with a brief description of their function.

ALLOFIT	Includes all agricultural, forestry, and carbon data as well as associated data calculations
FAMODEL	Defines the FASOM optimization model
FARPT	Set, alias, and parameter definitions for report writer
FABASRUN	Causes the base model and the report writers to be run. Policy experiments may be run using FAAGTREE, FACARRUN and FAALTRUN.
FAFINAL	Prints a summary report of aggregate results comparing across the runs made

Users may also use an advanced basis in the case of problem cold starts. Using the alternative batch file BASIS and the statement INCLUDE "FABASIS.BAS" in FAMODEL incorporates that basis.

FASOM contains 4 switches that may be set which radically alter the type of model being analyzed. These are set at the top of the FAMODEL but may be reset anywhere below that point. These switches and their functions are:

YESAG	A switch which controls whether the ag model is generated. A nonzero value activates the ag model while a zero value suppresses it.
YESFOR	A switch which controls whether the forestry model is generated. A nonzero value activates the forestry model while a zero value suppresses it. When both this switch and YESAG are nonzero the full FASOM two sector model is solved.
SEPAG	A switch which tells whether the nonlinear or separable model version is generated for the agricultural problem. Currently the separable version is required to obtain convergence in the full 100 year ag and forestry FASOM version. The ag model will run either way when the forest model is suppressed.
SEPFOR	A switch which tells whether the nonlinear or separable model version is generated for the forestry part of the problem. Currently the separable version is

	required to obtain convergence in the full 100 year ag and forestry FASOM version. The forest model will run either way when the ag model is suppressed.
LIM	Number of farm program iterations. If equal to one this suppresses farm program iterations

D3.0 FILE FUNCTIONS AND SEQUENCE

As previously stated, the five files called in the batch file, in turn, call various associated files and control the specifications of model setup, solution, and output processes. These are described below.

Table D-3. Operations of the Five Primary Files

	Primary Files				
Operations	**ALLOFIT**	**FAMODEL**	**FARPT**	**FABASRUN**	**FAFINAL**
Include Files	5	3	0	4	0
Put Stmts	0	0	0	0	0
Model Settings	0	5	0	0	0
Options	2	4	0	6	Many
Loops	0	0	0	1	0

ALLOFIT

This file includes the following:

< **include files**:
FASETS - core model structure
FAFORDAT - forestry sector data
include files:
CAP.PRN
TRADEDMD.PRN
PUBLIC.PRN
INV.PRN
EXIST.PRN
NEW.PRN
EST.PRN
GROW.PRN
INTER.PRN

FPDMD.PRN
ROTATE.PRN
FAAGDAT.PUT - agriculture sector data
include files:
FAAGDYN - ag. sector dynamics
FACARBON - carbon data
FAASMCAL - ag. data calculations
BIOMASS.PRN - Biomass data

FAMODEL

This file includes the following:

- **include files**:
  FAPOLDAT -policy alternative sets
  FAMODSET - separable programming sets
  FABAS.BAS - (optional) .l,.m values for advanced basis start
  DEF - Guess at deficiency payment

- **Key model settings**:
  YESAG - include ag model ?
  YESFOR - include forest model ?
  SEPFOR - do forest model in separable fashion?
  SEPAG - do ag model in separable fashion?
  LIM - number of farm program iterations
  SOLVE stmt.

FABASRUN

This file includes the following:

- **include files**:
  FAFORRPT - forestry data report writer
  FACRBRPT - carbon data report writer
  FAASMRPT - ag. data report writer
  FACOMPAR - alternative run comparison report writer
  CEA - Council of Economic Advisors Scenario data
  PUB185.PRN - Public cut scenario data
  PUB187.PRN - Public cut scenaro data
  RECYCLE - Recycling Scenario dta
  MINHARV.RES - Minimum harvest use restriction data

  - **Key options**

Scenario Control Loop

LIM - Farm program iterations

D3.2 FLOW CHART OF MODEL SEGMENTS

```
ALLOFIT
  |     <FASETS
  |     <FAFORDAT
  |     <CAP.PRN
  |     <TRADEDMD.PRN
  |     <PUBLIC.PRN
  |     <INV.PUT
  |     <EXIST.PUT
  |     <NEW.PUT
  |     <EST.PRN
  |     <GROW.PRN
  |     <INTER.PRN
  |     <ROTATE.PRN
  |     < FPDMD.PRN
  |     <FAAGDAT.PUT
  |     <FAAGDYN
  |     <FACARBON
  |     <FAASMCAL
  |
FAMODEL
  |     <FAPOLDAT
  |     <FAUPDATE
  |     <FAMODSET
  |     <FABASIS.BAS (optional)
  |     <DEF
 FARPT
  |
  |    <CEA
  |    <PUB185.PRN
  |    <RECYCLE
  |    <PUB187.PRN
  |    <MINHARV.RES
FABASRUN  < FAFORRPT
  |    <FACRBRPT
  |    <FAAGWEL
  |    <FAASMRPT
  |    <FAFORWEL
  |    <FAFORLOT
  |    <FACOMPAR
```

FAFINAL

APPENDIX E

FASOM OUTPUT FILE CONTENTS

Summary FASOM output is produced in the FAFINAL.LST file by the GAMS instructions. Other output also appears in the alternative runs files (FABASRUN, FAAGTREE, FAALTRUN, FACARRUN) and in the detailed forest sector output file FAFORRPT. This appendix defines a number of the items appearing in these output files.

E1.0 COMBINED FOREST AND CARBON SECTOR OUTPUT[35]

The following information is provided as output to the model:

FAWELFARE The Net Present Value of forest sector Welfare, including consumers' surplus, producers' surplus, foreign interests' surplus, returns to public cut, and terminal conditions. The units of this are million dollars. The components of this table are:

DOMESTCON	Forest products domestic consumers' surplus
DOMESTPRO	Forest products domestic producers' surplus
PUBLICCUT	Public cut surplus which actually is total revenue to public cut since public costs are not included
DOMEST	Total of above three measures
ALLFOREIGN	Forest products surplus to foreign imports and exports note this is just foreign surplus since the curves are excess supply and demand relations and cannot be interpreted as consumers or producers surplus for particular parties
ALL	Total of DOMEST + ALLFOREIGN
TERMINAL	Consumers' surplus to the terminal conditions
GRAND	Total of ALL + GRAND -- interpretable as total NPV of welfare

FAWELFAREP	Percentage changes in FAWELFARE from the base scenario. Note a 1.0 value means a 1% increase from the base
NETWELF	Net Present values of total welfare less program costs.This has the GRAND data from the FAWELFARE table the NPV of sips program costs (SIPCOST) based on data in the SIPCOST table and their difference (BOTTOMLINE=GRAND-SIPCOST)
NETWELFP	Percent change in NETWELF
PROGCOST	Program cost by decade and type of policy

---

[35] Carbon sector outputs include carbon associated with existing inventory processes, afforestation, and reforestation.

TIMBERINV	National Timber Inventory by decade in thousands of acres.This table also reports ownership, species and management intensity class. The ownership classes are OP for other private and FI for industrial forests. The species are SOFSOF for softwood following softwood, HARSOF for softwood following hardwood, SOFHAR for hardwood following softwood, and HARHAR for hardwood following hardwood
TIMBERINVP	Percentage change in TIMBERINV
TIMBERHAR	National Timber Harvest by decade in thousands of acres This table also reports ownership, and species. The ownership classes and species are as above
TIMBERHARP	Percentage change in TIMBERHAR
CARBONINV	Metric tons of carbon in inventory by decade in millions of tons
CARBONINV	Percentage change in CARBONINV
REGCARBINV	Metric tons of carbon in inventory by decade and region in millions of tons
TIMBPRICE	Forest Product Price in $ 1990 / CF by decade and product for pulpwood, sawtimber and fuelwood from softwoods and hardwoods
TIMBPRICEP	Percentage change in TIMBPRICE
TIMBPROD	Forest Products Production by decade and product in MMCF
TIMBPRODP	Percentage change in TIMBPROD
TIMBCONS	Forest Products Consumption by decade and product probably in MCF
TIMBCONSP	Percentage change in TIMBCONS
CARBFLUX	Annual carbon addition in million metric tons/yr
CARBFLUXP	Percent change in annual carbon addition
TIMBPROP	Timber producers price index relative to the base
TIMBPROQ	Timber producers quantity index relative to the base
TIMBCONP	Timber consumers price index relative to the base

TIMBCONQ	Timber producers quantity index relative to the base
PROGACRES	Thousands of acres enrolled in policy programs
TIMBINV	Total softwood and hardwood timber inventory in million cu ft
REFOREST	Thousands of acres reforested by MIC and owner for entire US
MICHARVEST	Thousands of acres harvested by MIC and owner for entire US
TNEW	An enumeration of all SIP acres in the last run, i.e., in the 50% and sip run

These tables are produced in FAFORRPT for each policy.

LANDDISP	Land actions by region and decade in thousand (M) acres:

HARVEXST	harvest of existing stands
HARVNEW	harvest of reestablished stands
CONVRTFRAG	land converted from ag
TRANSFER	land lost or added to the forest base due to urban/suburban, infrastructural, and other nonfarm actions
REFOREST	land "replanted" to any of the MIC classes (including LL)
CONVRTOAG	land shifted from forest to ag

SOFTEXIST	Harvest of existing softwood acres, displayed by region, land class, owner, species, site quality: then the rows show initial age class (cohort) and MIC class and the columns show the decade of the projection in which harvested
HARDEXIST	The same thing as SOFTEXIST for hardwood species groups
SOFTNEW and HARDNEW	Show comparable detail for reestablished stands. Each block is for region, land class, owner, species, and site quality. The rows give the MIC when regenerated and age of harvest in decades (so PLUS40 is 40 years, etc.) and the columns show the period in the projection in which the stand was regenerated (planted). So if you add the age of harvest to the decade regenerated you can tell when the stand is next cut (e.g., 1990 + 40 = 2030). Acres in 1,000s
NETRADE	Shows by region, decade and product then net offshore trade of the various regions: a positive number is a net export, a negative number a net import. Volumes in million cubic feet

CONSBAL	Shows total US consumption, production, substitution, imports, exports and apparent consumption (as a check) of products by decade. Volumes are in million cubic feet. At times the apparent consumption check column will show a larger volume than the consumption column. The latter is the "real" amount consumed since it is possible to harvest material and not use it or downgrade (substitute) it--this may have some interesting carbon accounting consequences. Note the USNETSUB is the net substitution column: a positive number is material received from a higher product category an minus is material shifted down to a lower product category (SAWT is higher than PULP is higher than FUEL)
LANDTOFOR	An accounting of land shifted to forestry from ag by region, decade and land class
FORTOAG	Represents land shifted from forestry to ag by region and decade
AGTOFOR	The same totals as from LANDTOFOR but summing across the land classes
SWINTOT, HWINTOT	Are total softwood and hardwood inventories (in million cubic feet) by owner, region, and decade

E2.0 AGRICULTURAL SECTOR OUTPUTS

The summarized ag output is at the end and gives the following information:

INDEXS	Fisher ideal price and quantity indices for a number of ag items giving the change in those items relative to the base model result by decade. The indices and the items in them are:

grain	CORN, SOYBEANS, WHEAT, SORGHUM, RICE, BARLEY, OATS
livestock	OTHERLIVES(MOSTLY HORSES), CULL DAIRY COWS, CULL BEEF COWS, MILK, HOGS SLAUGHTERED, FEEDER PIGS, LIVE CALVES, BEEF YEARLINGS, CALVES SLAUGHTERED, NONFED BEEF, FED BEEF, CULL SOWS, POULTRY, LAMBS SLAUGHTERED, LAMBS FOR FEEDING, CULL EWES, WOOL
othercrop	SILAGE, HAY, COTTON, SOYBEANS, SUGARCANE, SUGARBEET, POTATOES

feeds	FEEDGRAIN, DAIRYPROT1, HIGHPROTSW, LOWPROTSWI, LOWPROTCAT,HIGHPROTCA, GLUTENFEED
processed	SOYBEANMEA, SOYBEANOIL, FLUIDMILK, BUTTER AMCHEESE, OTCHEESE, ICECREAM, NONFATDRYM, COTTAGECHE, SKIMMILK, CREAM, HFCS, BEVERAGES, CONFECTION, BAKING, CANNING, REFSUGAR, CANEREFINI, CORNOIL, ETHANOL, COSYRUP, DEXTROSE FROZENPOT, DRIEDPOT, CHIPPOT, STARCH
meats	FEDBEEF, VEAL, NONFEDBEEF, PORK
chemicals	NITROGEN, POTASSIUM, PHOSPOROUS, LIMEIN, CHEMICALCO
otherinput	OTHERVARIA, PUBLICGRAZ, CUSTOMOPER, SEEDCOST, CAPITAL, REPAIRCOST, VETANDMED MARKETING, INSURANCE, MACHINERY, MANAGEMENT, LANDTAXES, GENERALOVE, NONCASHVAR, MGT, FUELANDOTH, CROPINSUR, IRRIGATION, MISCCOST,PROCCOST, TRANCOST, MISCINPUT

AGTABLE Table of agricultural results which summarize a number of items by decade. They include:

CROPLAND	Use of crop land in thousand acres
PASTURE	Use of pasture land in thousand acres
DRYLAND	Use of dryland crop land in thousand acres
IRRIGLAND	Use of irrigated crop land in thousand acres
WATER	Use of irrigation water in thousand acre feet
LABOR	Use of labor in thousand hours
TOTALWELF	Total surplus in ag model in thousand $
CONSWELF	Total domestic ag consumers surplus in ag model in thousand $
PRODWELF	Total domestic ag producers surplus in ag model in thousand $
FORWELF	Total foreign surplus in ag model in thousand $
DOMESTWEL	Total domestic surplus in ag model in thousand $
GOVTCOST	Total government program cost in ag model in thousand $
NETWELF	Net ag surplus after subtracting government cost in thousand $
TRADBAL	Ag trade balance in thousand $