Boreal Conservation

Hydrology and Forestry in the Alberta-Pacific FMA area

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Executive Summary

Water resources are vast and complicated in the boreal plain. Geology is dominated by deep soils ranging in permeability from coarse gravels to lacustrine clays. Water exists not just on the surface but also near the surface (shallow groundwater), as local groundwater (deeper yet) to regional groundwater (<30m). All this water moves and depending on the depth and the geology involved, it can take days or years to emerge to the surface again. These subsurface groundwater systems can be altered by disturbance on the surface that alters flow paths. Alteration of flow paths can result in degradation of water quality, quantity and cause undue cost to industry.

In recent years, the boreal plain has undergone rapid transformation from a wilderness to a region of commercial developments, particularly in northern Alberta and northeastern British Columbia. A total of 21% of Alberta's productive forest has been harvested and another 45% percent is scheduled for harvest. Logging and the extensive network of roads necessary to access and remove the harvested trees, in combination with petroleum extraction, gas-well installations, and the clearing of corridors for seismic and road access, have created thousands of kilometers of linear disturbances in Alberta's boreal zone.

With increased development of the boreal plain an inherent risk to water has emerged. This paper defines an approach to identify and minimize risk of altering surface and groundwater and allowing industry to continue in adaptive environmental and cost effective way.

I
Introduction

Forest Operations and Water

Water conservation and wise use has been identified as a priority for the Province of Alberta and has given rise to the Provincial Water Strategy. The Province has set targets around protection of water quantity and quality in light of recent shortages of surface water in southern Alberta and quantity/quality issues of groundwater in northern Alberta.

Alberta-Pacific has been compliant with existing water protection legislation and has gone further in some cases. Initiatives like Terrestrial Organisms in Lakes and Streams (TROLS), Hydrology, Ecology and Disturbance of Boreal wetlands (HEAD), and individual studies with the University of Alberta have increased the state of knowledge around water in the Western Boreal Forest and in the Al-Pac Forest Management Agreement Area (FMA area).

In the past hydrological aspects of studies were added on to existing biotic experiments. These multidisciplinary experiments yielded unclear results to direct forest operations in terms of risk to aquatic resources. In the HEAD project the design was to focus research on hydrologic questions; biotic responses were monitored as an output of the different hydrologic units.

Recent findings from the HEAD research have challenged the long-standing practice of interpreting hydrologic function (how water moves) in a given landscape (see Devito et al. 2005). A topographic approach can work for shallow soils on impervious bedrock in humid climates. In Alberta however, because of the complex interaction with climate, soils, geology and surface and groundwater, topography is not a good predictor of water movement (see also Winter 2001).

Research on surface and sub-surface water in and near the Al-Pac FMA area has given insights into potential risks to water flow and water quality from forest operations (Devito et al. 2005). Risk is defined as a potential negative result from operations activities that may involve a detriment to Al-Pac in terms of dangerous road conditions, environmental damage, and increased construction and maintenance costs. This paper will describe those risks and their potential to affect current forestry and roading practices.

Specifically we anticipate the following benefits from hydrological research:

1. Knowledge of relative sensitivities of aquatic and wetland systems to disturbances such as logging and roads based on the position of these systems in the landscape.

2. Guidelines for inclusion or exclusion of particular types of land-use activities (Oil and Gas development and Forestry) based on longer-term weather patterns (rainfall and runoff).
3. Ability to predict potential impacts of anthropogenic activities on physicochemical attributes that ultimately influence the biotic components of aquatic systems
4. .Development of BMP's that address hydrologic risk considerations
5. Development of a streamlined, cost effective process to identify locations within the FMA area that are sensitive to disturbance

II
Hydrology in the Al-Pac Forest Management Agreement Area

Industry and Hydrology Interactions

Oil and gas development and forestry are multi-billion dollar industries and the mainstays of Alberta's economy. Their affect on the environment is equally significant. Pressure from government agencies, environmental groups and international markets on resource-based industries to act in environmentally responsible ways is of real financial concern for industry. At the same time, the goal to restore or reconfigure the harvested/mined region into an ecologically productive and sustainable landscape offers tremendous opportunities to mitigate impacts.

Presently, there is a lack of information or guidelines about how resource extraction activities affect hydrologic processes in the FMA area. We believe there are significant interactions that have environmental, social and financial consequences. A model for the boreal plain has been suggested to assess the sensitivity of hydrologic systems based on a hierarchical approach beginning with climate, geology, organic content and finally topography.

The Boreal Plain – unique climate and geology

The Canadian boreal plain represents one of the largest forested regions in the world. It extends from northeastern British Columbia to southwestern Manitoba, covering over 3 million square kilometers. (Figure1). When compared to other ecoregions of Canada, the boreal plain is a forested region with unique climate and geology. The Boreal Plain has deep glacial deposits of sands, silts and clays overlying permeable bedrock and sub-humid climate. This contrasts the Boreal Shield geology which has shallow soils over impermeable crystalline bedrock, and humid climate.. These two regions differ in available water, dominance of lateral flow and thus susceptibility to forest practices (Figure 2). Precipitation over the Boreal Plain of Alberta ranges roughly from 400 – 500 mm per year, while PET ranges from 500-600 mm. The long term water deficient (see Woo and Winter 1993) results in low runoff and dominance of soil storage (Devito et al. 2005). The reduced runoff in the Boreal Plain results in lower susceptibility to impacts of harvesting activities relative to the humid eastern Boreal Shield (Figure 2 and 3). With respect to nutrient loading, the high weathering rates of calcareous rock in the Boreal Plain results in surface waters with high nutrients, and generally higher productivity relative to the Boreal Shield. This may further reduce potential impacts of harvesting. Currently, there is a lack of understanding regarding hydrologic interactions in the Boreal Plain that incorporates climatic and landscape variability.

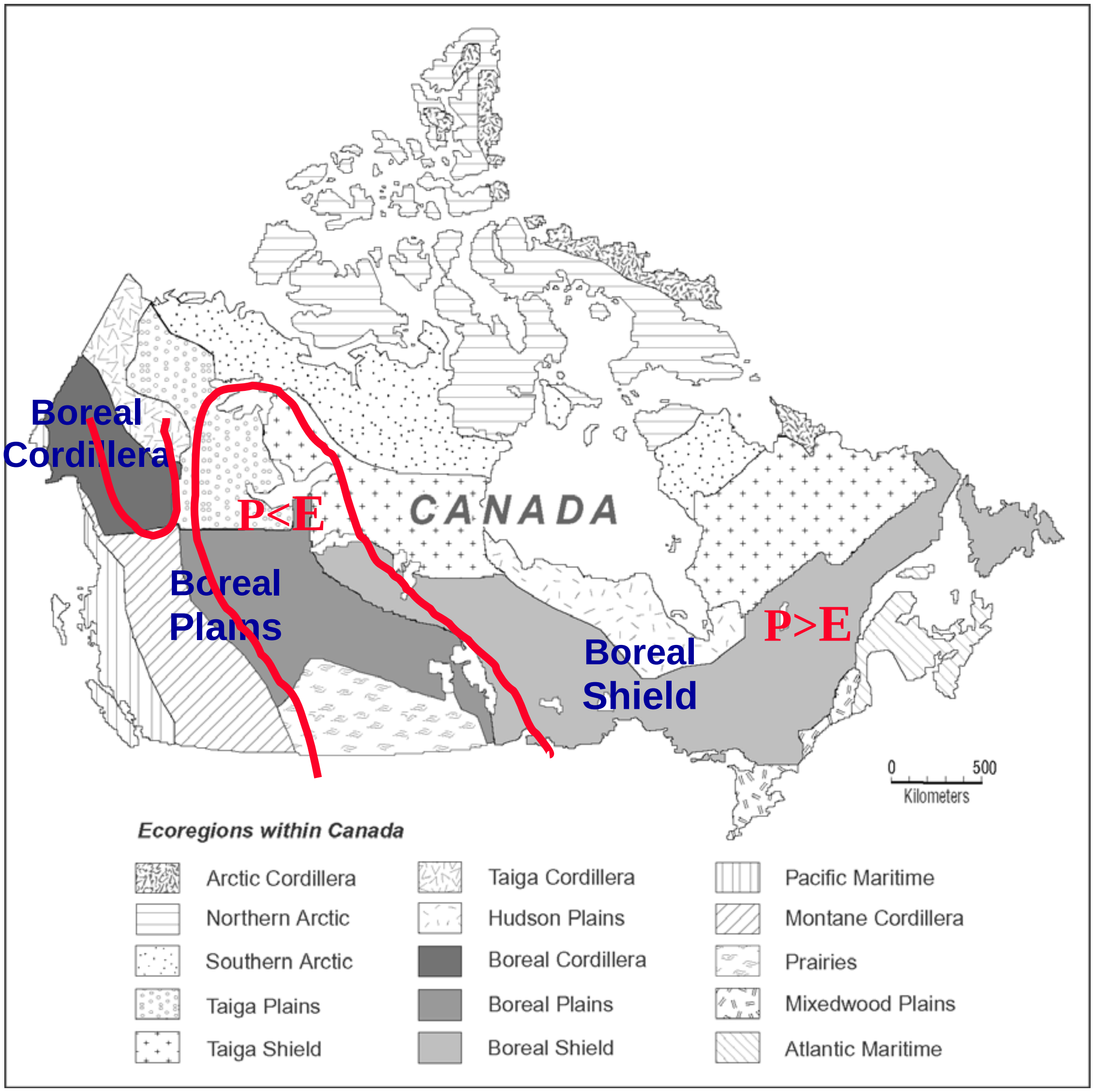


Figure 1: Ecoregions within Canada, showing regions of distinct climate, geology and vegetation with similar, and often unique hydrologic properties. The line shows location where precipitation (P) equals potential evapotranspiration (PET). Sub-humid to arid areas of Canada located within south west. Extrapolation of forest practice policies with respect to hydrologic risk should be restricted to with ecoregions and between sub-humid (P<PET) and humid (P>PET) regions. From Buttle et al. 2005

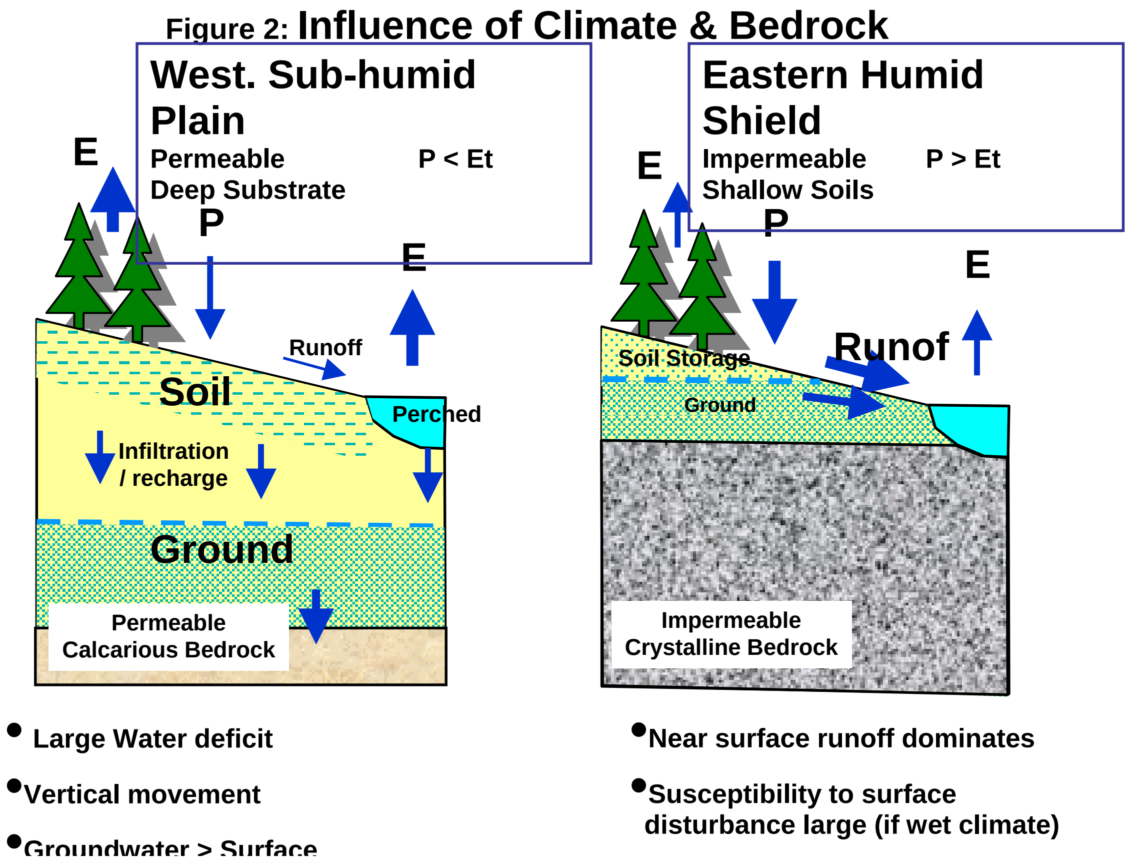


Figure 2: Comparison of sub-humid Boreal Plains and humid Boreal Shield hydrology illustrating the influence of climate and geology on dominant water storage and flow paths in catchments. IN the sub-humid climate characteristic of the Boreal plain, soil storage dominates and water flow is predominantly vertical resulting limited near surface flow and lower susceptibility to surface disturbance.

Climate interaction with geology

Our FMA area is classified sub-humid, with soil moisture in water deficit as potential evapotranspiration (Et equals or exceeds precipitation (P) over the long term). However, the FMA area is comprised of two regions that vary in climate enough to warrant consideration (fig. 2).

Differing climates (precipitation, evaporation) will interact with geological formation or soil type differently (figure 3). Generally in the FMA area, runoff coefficients (percent runoff of precipitation) are low (<20%) because of the drier climate of much of the FMA area. Forest vegetation is water deficient; soils are usually dry following summer and absorb most rainstorms. Snow accumulation is low, thus there is generally reduced risk of runoff for most of the FMA area, as compared to humid areas of Canada (eastern Boreal, west coast).

Where precipitation is less than evapotranspiration (evaporation and transpiration from vegetation) most soils are stable and can withstand moderate amounts of disturbance. An example of this would be on fine-grained materials such as clays or silts. If the region had less precipitation than evaporation (which is the case for a large part of the FMA area) then soils would remain relatively dry and not produce runoff. Forest operations on these soils would not likely create any water-related negative effect.

When precipitation is equal to (or greater than) evapotranspiration soils can become saturated and unable to withstand minimal amounts of disturbance. (See fig. 2). Higher runoff does occur on occasion in the FMA area (about 1 in 10 to 20 years), and during these years the risk is increased. In the FMA area, years of increased runoff are somewhat predictable; being associated with wet falls (Sept. and Oct.), and higher soil moisture. Years following a “wet fall” with a “wet summer” can result in large increases in surface flow.

If the same fine-grained materials were exposed to a climate that had precipitation equal to or in some areas greater than evaporation (which is the case in the north eastern part of the FMA area) the risk of forest operations creating negative effects is likely in non-frozen conditions.

Detailed soil maps are available for certain regions of the Al-PacFMA, full coverage is being evaluated by the Boreal Conservation Project Science Team and may be adequate for planning purposes

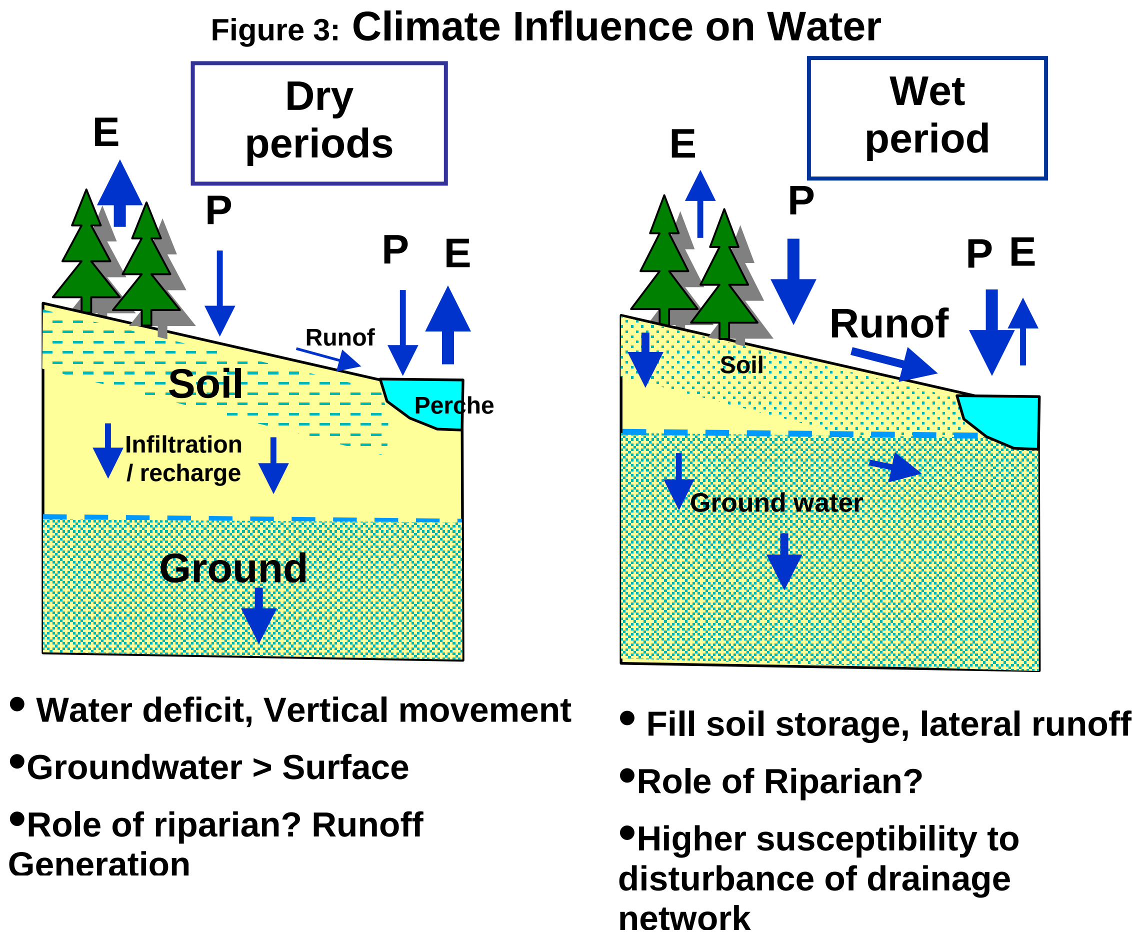


Figure 3:Comparison of dry and wet period hydrology on the Boreal Plain, characteristic of regions with deep substrates. On the Boreal Plain, wet periods generally occur every 10 to 15 years and require two wet years to recharge soil storage and create significant runoff.

Influence of Surficial Geology on flow and susceptibility

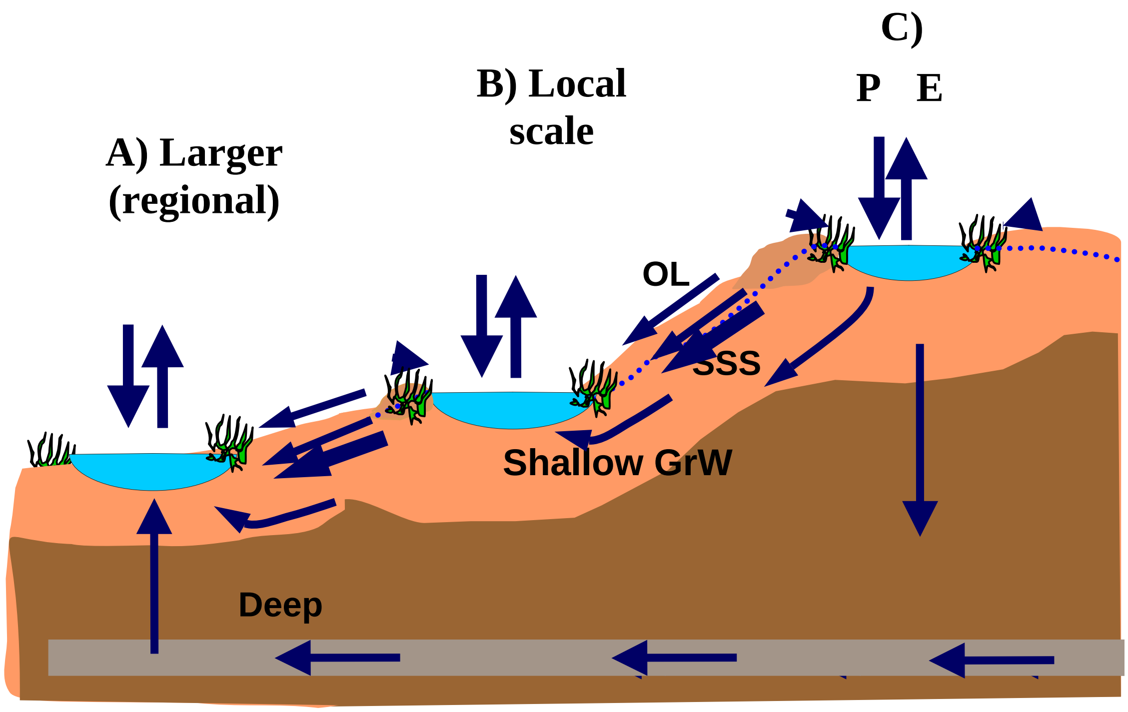
Water will always flow to the path of least resistance and may flow over the surface (high risk) and under ground (generally lower risk). Deep substrates of the Boreal Plain result in complex hydrology of surface flow and different scales of groundwater flow (figure 4). Thus aquatic systems may have a range of interactions, or hydrologic connections, with the surrounding landscape (Figure 4). The linkages to the surrounding landscape influences to susceptibility of aquatic systems to activities in adjacent uplands. Generally the more that human activities interact with upland to aquatic system linkages the greater the risk. Figure 4 illustrates that topographic high systems with little interaction with surrounding landscape are less susceptible to roading or harvesting activates due to isolation. Aquatic systems receiving surface and shallow groundwater inputs from adjacent uplands have higher sociability and risk. Deep groundwater sources do not originate from where the forest activities occur on the hill slope, and serve to buffer the impact.

Subsurface and surficial geology can range from extremely porous (gravels and sand) to impermeable (clays and bedrock). This can determine the dominance of surface and subsurface flow (potential risk) as well as the scale (distance) of interaction and potential disturbance. In porous systems (i.e. glacial-fluvial outwash sands and gravels, and aeolian sands) water can move underground for many kilometers before returning to the surface? Movement of groundwater may take years from recharge (go underground) to discharge (springs, seeps, stream or river beds). Water tends to move vertically, and in these systems because of downward movement there is little surface flow. This type of system is relatively low risk for forest operations, such as roads, that affect near surface flow. Permanent or summer road placement is appropriate for these geologic areas in isolated and intermediate locations. Consideration of susceptibility to groundwater discharge and road icing must be made in low-lying areas of coarse deposits

In impermeable systems (clay/silt rich moraines, low lying plains) water cannot move vertically for a great distance through the soil. If the soil is dry it may absorb precipitation on slopes. Once the soils are saturated water will move laterally down hill. A large rain event or a rainy summer will make this area a definite risk for forest operations. Winter road placement is suggested in impermeable systems (fig.3)

Unique geology applies to situations where coarse sands lay over clay (also called “sandy veneer”). The sand allows for vertical movement of water with limited opportunity for plant uptake and results in more runoff than other landforms. However, the downward moving water rapidly intersects clay and moves laterally along this confining layer. Increased runoff is expected in these cases. Road building can intersect this “shallow flow” and is at higher risk of interrupting water movement and increasing roading costs. These areas occur in specific locations across the FMA area and have been identified in the Alberta Geological survey maps. An example of this would be in the north east of the FMA area where only 50 cm soil over lays bedrock.

The Logan pit road is a good example. The road was cut into a hillside that had shallow (< 1m.) groundwater flow. The interruption of groundwater forced overland flow to the surface of the road all year round. This condition increased maintenance costs and created unsafe road conditions for Al-Pac to maintain drainage in summer and remove heavy ice from the road in winter.



By Devito, modified from Hill, Devito, Bedford

Figure 4: Variation in dominant hydrologic components and linkages to the surrounding environment of aquatic systems in isolated, local and intermediate groundwater flow systems. The water table responses to climate change and susceptibility of aquatic systems to disturbance in adjacent uplands will vary with aquatic systems position in the landscape.

Upland vs. Wetland Soils

Uplands have drier mineral soils (low organic content), high evapotranspiration rates (vegetation emitting large quantities of water), and generally low runoff in most years. Peatlands have high organic content, which limits the depth that plant roots extend and produces lower evapotranspiration (water loss via plants) than upland vegetation. Lower evapotranspiration along with soil properties generally results in water-saturated surfaces, which reduce absorption of rain, allowing peatlands to produce runoff more regularly than other landforms. Along with peatlands, ephemeral draws have soils intermediated between uplands and wetlands, and are areas of runoff generation in most years. Care should be taken when harvesting or road-building near wetlands and ephemeral draws, which are susceptible to blockage of surface flows. The degree of risk will increase with increase in fines (confining layers) and topographically lower location that receive more runoff. These regions usually have an abundance of peatlands. Peatlands in low-lying regions with deep coarse deposits may receive large inputs of groundwater (figure 4). Road impacts on drainage and vegetation may be low, as water can flow over and under, however, road failures and winter icing problems may arise.

Distinction of wetland and mineral soils is also important in understanding nutrient transport. Upland soils have the lowest risk of a nutrient release because they are drier and have little potential to involve groundwater or release organic material. Only when upland soils become saturated would there be a risk of organic movement of low nutrient content. Wetlands are at a much higher risk of a nutrient release. Hydrologic disruption (such as a road or pipeline) of a wetland system will involve an organic response (large nutrient release, methane or CO_2), a physical response where water will change its flow path, a vegetative response (to nutrients, flows, water levels) will cause a shift that may take several years to finish and, a wildlife response as wetland habitat conditions undergo change. Peat land road crossings should occur, when possible, at upper most elevations where lateral flow is limited.

Topography

Topography has been used in the past to define where water moves in a give watershed. Topographic position is important in defining potential linkages to the landscape (Figure 4). However, prior knowledge of surficial geology and peatland distribution is required to assess actual linkages and scale of interaction to the surrounding environment. It is now suggested that topography be utilized in the assessment of risk after consideration of the Climate, geology and organic content. In the low relief areas of the boreal, generally topography should be considered last. Topography of impermeable geological formations can be used to predict where groundwater may interact with surface disturbance.

Unique Features

Buried glacial melt water channels exist sporadically across the landscape. Even though the chance of occurrence is low they should be avoided. The Alberta Geological Survey has identified many of these channels. Buried glacial melt water channels in general have permeable material and can exist in otherwise low permeability geological formations. Melt water channels were formed as glaciers receded and could pose a risk to operations if interrupted by road or compaction. Water continues to move through these formations that are similar to a permanent stream in behavior. Underground rivers are usually deep but could present drastic effects if contaminated by spills.

Groundwater springs coming from permeable bedrock (potentially in north eastern FMA area) are areas of permanent water flow and care should be taking not to block outflow waters with road works. In contrast, water from the spring does not originate from local hill slopes, and there is generally low risk to interrupting the source water.

III
Integrating Hydrology and Forest Operations

Forestry has to date used topography and surface water hydrology to define watersheds. In the boreal plain this approached we believe is not correct. By integrating climate, geology, organic content and topography into a model truly functional watersheds can be defined. The potential for industrial development to affect a functional watershed may also be foreseen using this approach. Risks to water and groundwater have been identified in a descending hierarchical approach (Devito et al., 2005a).

A summary of range of hydrologic conditions, linkages to surrounding environment, and relative responses of aquatic ecosystems to rainfall for the Boreal Plain is provided in Table 1. The criteria should be utilized in ascending order to define unique hydrologic units.

Table 1 Range of hydrologic conditions and responses of Boreal Plains Systems for hierarchy of Criteria

Criteria	Range of index	
	Low Risk	High Risk
Climate	**Dry to sub-humid P$\leq$E** -Soil storage large, little runoff, vertical water movement	**Wet, humid P>E,** -Runoff related to precipitation, lateral water movement
Geology	**Glaciated, permeable,** -Vertical water movement	**Impervious bedrock,** -Simple hydrology, lateral water movement
Surficial Geology (Permeability)	**Coarse grained** -Ground water dominates subsurface, vertical drainage	**Fine grained clays and** silts -Surface flows, water ponds in low areas
Organic Content (uplands/peatlands)	**Mineral soils** -Subsurface storage, plant evapotranspiration, low runoff in sub-humid areas	**Wetland/peat land** - Saturated surfaces, lower evapotranspiration during drought, runoff normally occurs
Topography- Drainage Network	**Gentle slopes, poor drainage network** - Low runoff, high groundwater recharge (vertical flow of water)	**Steeper slopes, organized drainage,** - Greater runoff, lateral flow
Unique Features		Melt water channels, underground rivers

The following section illustrates how assessment of the relative susceptibility of aquatic systems to disturbance can be made from delineation of hydrologic sources or linkages to the surrounding landscape

There are four general categories of risk:

1) Potential increases in flow brought on by harvesting, reduced water uptake by forests and increased surface flow. Increased flow can result in sediment and increase nutrient movement (linked to shallow soils that are saturated).
2) Blockage of natural surface water flows by roads and incorrect placement of culvert, or road failures in areas of surface flow
3) Road crossing of larger streams and rivers, potential bridge failures and sediment introduction to streams
4) Contamination of Subsurface (ground) water, via pipeline failures etc.

In this paper, we address risks (for 1) and 2) above) by interrupting water source and flow that can be inferred by current research and understanding of the major controls of water movement and how aquatic systems interact with their surroundings. Table 2 illustrates the relative risk of 1) and 2) above associated with each of the criteria

Table 2 Water risk based on geology and landuse

Climate	Geology	Surficial Geology		Soils/ organics	Topography		
Humid /Wet	**Impermeable Boreal Shield**					**Harvesting Risk**	**Road Risk**
(higher risk)	**(higher risk)**			**Mineral (aspen)**	**Low-lying Connected**	**incr. base flow**	**Road ice**
			Deep Coarse Substrate		**High Isolated**	**low**	**low**
				Wetland (peat)	**Low-lying Connected**	**low**	**Road icing Low risk veg**
		Coarse Grain Vertical/recharge			**High Isolated**	**low**	**Low**
				Mineral (aspen)	**Low-lying Connected**	**High Peak flow**	**Road failure Icing**
			Sand veneer <2m over fine		**High Isolated**	**Moderate**	**moderate**
Sub-Humid/Dry Vertical	**Permeable Calcarious Complex deep**			**Wetland (peat)**	**Low-lying Connected**	**High Peak flow**	**High Block flow veg impact**
flow Lower risk	**substrate (lower risk)**				**High Isolated**	**Low**	**Low**
				Mineral (aspen)	**Low-lying Connected**	**Dry-low Wet-high**	**Dry-low Wet-high**
		Silt/clay/sand Moraine			**High Isolated**	**Low**	**Low**
				Wetland (peat)	**Low-lying Connected**	**moderate**	**Road block Veg impacts**
					High Isolated	**low**	**Low**
		Fine Grain/clay Lacustrine		**Wetland (peat)**	**Low lying Connected**		**High- icing Veg impacts**
					High Isolated		**Moderate**

III
Application of the Hydrologic Assessment Model at a landscape scale

The goal of this section is to introduce a comprehensive approach to evaluating the risks relating to hydrology and forest operations (including roads). Past practices were to operate without knowledge of interaction with groundwater and deal post effect with a clean-up or poor road condition. By evaluating risks to hydrology, road costs and possibly safety at the front end of the planning cycle both water integrity and Al-Pac can benefit.

To fit within landscape planning the hydrologic assessment model should be integrated into the planning process at Al-Pac. This risk analysis would be part of a GIS planning exercise and be incorporated directly into the Al-Pac Woodlands Information System (WIS). The screening of FMU's through to harvest blocks would be able to identify hydrologic risk based on the following steps. (Note the status of data is listed under each step.)

1. **Define the climatic zones**
    - In general the AlPac FMA is in water deficit and experiences low runoff. Two regions may be identified to date exhibiting differing annual precipitation patterns and average amounts
    - Generally there is greater P in the southwestern portion where P equals PET. There is lower P in eastern portion of the FMA, were P is less than PET (100-200 mm deficit)
    - Maps of these areas are being generated, however Environment Canada provides a guide

2. **Define underlying bedrock geology**
    - This data currently exists for the FMA area
    - Ranges from shallow soil depth (< 50 cm.) to bedrock in the east, to deep soils over bedrock (>100 m.).
    - Most of the glacial till has low permeability and limits interaction with bedrock aquifers.
    - 1:20,000 scale or finer is needed

3. **Define the Surficial geology**
    - This data currently exists for most of the FMA area
    - Quality of this data is being assessed
    - Data describes a range from coarse grained (groundwater) to fine-grained (surface water) material that varies within township and smaller spatial scale.
    - Sensitive features: such as melt water channels, or sand veneers over clay that pose a significant threat to roads
    - 1:20,000 scale or finer is needed

4. **Define the Organic content (soil types)**
   - This data currently exists for some of the FMA area
   - Quality of this data is being assessed

5. **Define the topography**
   - This data exists for the FMA area
   - Data is coarse (based on 25m elevation intervals)
   - Some features such as ephemeral draws and wetlands in clay soils may also pose a threat to harvest and roading activities.

A <u>simulated</u> output for the L1 planning unit:

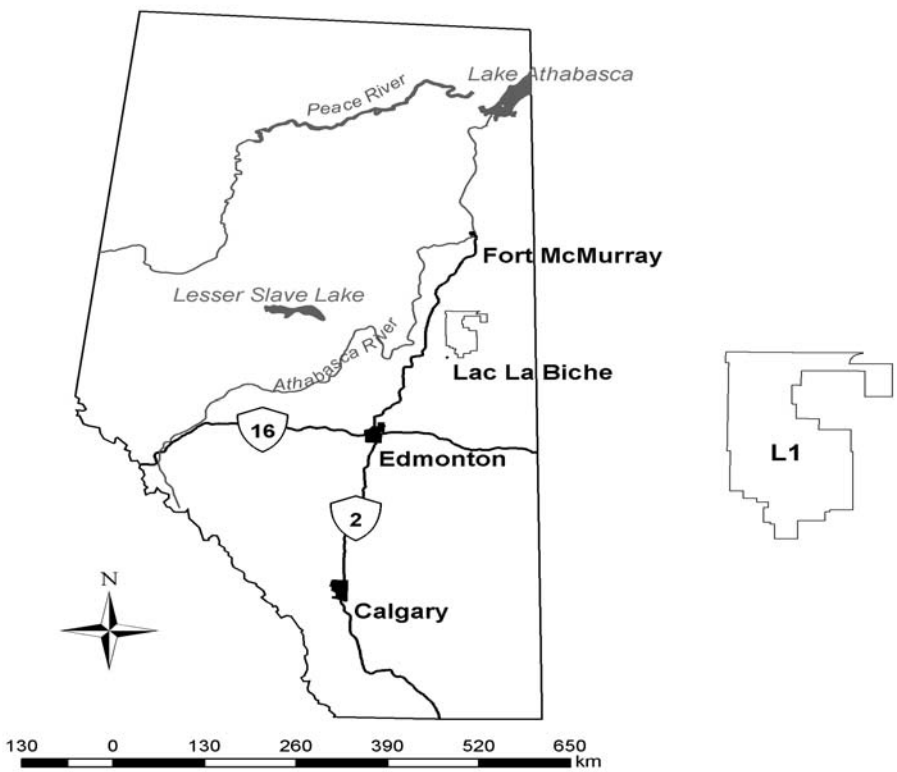


Figure 5: The L1 planning unit is approximately 30 townships in size including lakes. Located north east of the town of Lac La Biche and bordered on the east by the cold lake air weapons range. The productive timberland base is less than half of the total land base at 130,000 hectares.

Related to Table 2

1. **Climatic zone** is moderate precipitation with lower evapotranspiration **(P ≅ E)**.
2. **Geology** is impervious bedrock and clays, simple hydrology, and has lateral water movement potential
3. **Surficial Geology** is fine-grained clays and silts. There is a strong possibility of surface flows and water ponding in low areas if precipitation is above normal for 2 or more years.
4. **Organic Content** in the upland soils of the harvest area if disturbed would allow the movement of nutrients to surface water flows.
5. **Topography** in the harvest area is composed of moderate slopes with organized channels that would transmit runoff.

Simulated recommendations for L1:

Forest harvest and road construction within this FMU must only occur when soil moisture levels are low in summer or confine all operations to winter. Conducting operations when soils are at or near saturated levels will result in compaction, rutting. Alteration of shallow groundwater flows will also alter nutrient movement in soils and surface water. Unstable soils (saturated) will have cost implications for existing roads and those under construction. These can be identified to the block level and roading and harvest plans can incorporate avoidance of unstable soils.

Sensitive groundwater features if small could be crossed by using methods such as corduroy or low-profile steel bridges. Larger features would be identified and avoided.

Safe conditions would be defined as soil moistures well below saturation with little chance of being saturated by normal rain events.

Permanent road locations must be outside any risk areas. If it is unavoidable, suitable drainage and design must be used to avoid environmental damage and large maintenance costs.

Application of the Hydrologic Assessment Model at a local scale

If it is unavoidable to operate on a potential risk location there are measures that can be taken to minimize a negative effect on groundwater.

Winter operations as a first approach

Winter operations on frozen ground are the preferred approach when working in sensitive areas. Roads can be "frozen in" limiting compaction of soils and no removal of roots or soil. Timely reclamation and abandonment of the site before thawing will ensure no lasting effect from harvest or roads.

Non-frozen

Operating in non-frozen conditions is the least desirable approach. Sites that can sustain disturbance in non-frozen condition are usually upland, well drained and have dry soils at the time of temporary road building or forest harvest. Permanent roads must be designed for 1:100 yr high water events and now include potential to affect shallow ground water and surface water wherever they are constructed.

Roads

Roads for Al-Pac forestry exist in six classes (see: Alberta-Pacific Forest Management Area Operating Ground Rules, 2000). The first four road classes (I-IV permanent) are for permanent roads and the last two classes (IV temporary and V) are for temporary roads. A permanent road is defined as providing access from more than 2 to more than 20 years (depending on class) and a temporary road can exist for less than two years. As the duration of the road increases also does its standards for cleared right-of-way, slopes on cuts and fills, ditching, radius of curve, size and type of stream crossing required. The size and permanence of a road will increase the likelihood of affecting surface and groundwater.

Permanent roads typically have a grade above existing soil profiles, defined ditches with cross-draining culverts and bridge crossings of any permanent stream. The grade of the road is constructed in compacted layer or "lifts" of impermeable material such as clay. Because of ditching and compaction most roads are barriers to surface and shallow groundwater.

Reclaimed roads may have had some decompaction but not enough to allow shallow groundwater flows in most cases. Most roads are not reclaimed but turned over to another user or kept open for future use. Temporary roads can become permanent if reclassified or another user wishes to take over the licence of occupation (LOC). An assessment of how many and what type of Al-Pac's LOC's have been taken over will be conducted in 2005.

Roads alter water movement. Ditches form a path of least resistance and direct water (surface and subsurface) in a course along the roadway. These flows are now concentrated in ditches and not along original pathways. The energy of these ditch flows is considerable and many erosion problem exist when storm waters overcome erosion control measures. The end point for most ditches is a stream, wetland or other water body. Silts and sediments tend to be carried into these systems creating harmful effects.

Ditching and roads also alter soil moisture. When water encounters a roadway (barrier) it follows along the ditch or ponds at the road. The site will wet up (more than before) and the opposite side of the road will not receive the water and become dryer than before the road was built. This is most prevalent in peatland wetlands that are lower in the landscape and with well-integrated drainage networks.

Best Practices for roads

Many of these best practices are already in use for various conditions. With the use of the hydrologic assessment model we can now identify climate, underlying and surface geology, organic content and topography along a road alignment at the preliminary planning stage. Interaction of the road with any of the steps of the model can be assessed and weighed against the cost of another alignment that has no or less interaction with the model steps. Consideration will be given to additional maintenance costs, safety, and disruption of a hydrologic system.

When interactions with a hydrologic system cannot be avoided at least the interaction will be known beforehand and appropriate measures can be in place to minimize the effects of the road.

A suggested best practice to use in this situation would be a combination of reviewing precipitation/soils data or GAS surficial geology maps (for risk of soil saturation). In addition, walking the road centerline for indicators such as wet areas, willow patches and pooled water. If the site must be crossed then a construction method should be employed to allow for the 1:50 – 100 yr flood drainage under the roadway.

At Al-Pac we typically avoid wetlands in our roading plans. Occasionally, a road is planned to cross a wetland. Wetlands are crossed at the narrowest points and in the case of capital roads they are treated as flowing systems whether being open water or fully vegetated wetlands. This means the crossing will allow water passage for the 1:50-100 yr flood. On temporary crossings wetlands are crossed in winter with ice bridges and snow fills. These crossings are opened up in late winter to allow water passage and complete melting when it warms up.

Peat land road crossings should occur, when possible, at upper most elevations where lateral flow is limited. This may not be the narrowest path across the peatland. In areas of significant lateral flow extra culverts may be required.

Topography of geological formations can be used to predict where groundwater may interact with surface disturbance. In impermeable systems, slopes and slope bases are poor choices for roads because that's where groundwater will move close to the surface.

Forest harvesting

The harvesting of trees involves large equipment and the potential to compact soils and cause surface disturbance (ruts). In most cases there is not significant damage to surface and shallow ground water due to tree removal practice. In block haul roads and skid trails would have the most potential to create an effect. The best practices that Al-Pac currently employs involve avoidance, discontinuing travel over soft areas and including adequate drainage for trails and roads.

In using the Hydrologic Assessment model, the benefit would be in the planning stage where wet or sensitive ground could be identified and a decision could be made to operate in a dryer year, during frozen conditions or go ahead. Costs could be budgeted for the site conditions giving some comfort to harvest cost forecasters.

Appendix I

Other Implications of developing a Hydrologic risk process for the FMA area

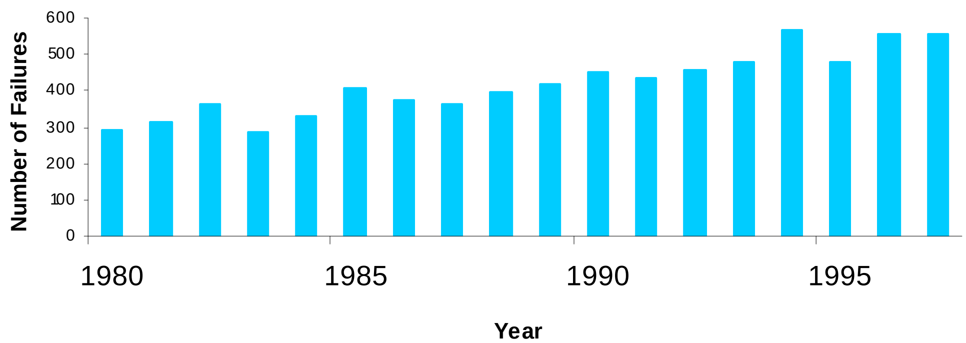
Forest harvest as a management tool

Forest harvest in conifer on impermeable subsurface geology has been shown to increase soil moisture and release water to adjacent streams. This has been used to provide needed water to address fisheries concerns. Primarily in the foothills this approach was used to increase flows to nearby streams. This may apply to streams in the birch mountains area and where impermeable subsurface geology and conifer stands are adjacent to fish bearing streams.

ILM

Other land use brings its own risk. Placement of pipelines through regional groundwater systems pose a great risk as spills would not be recovered and could be transmitted for kilometers and contaminate many groundwater and connected surface water systems. Routing of pipelines to avoid high-risk areas is an option to protect groundwater quality for the future. Pipeline failures are unfortunately a common event in Alberta (AEUB, 1998) (fig.6)

Figure 6. Number of oil and gas pipeline failures in Alberta, 1980-1997. Source: AEUB, 1998.



Groundwater resources for industrial use will be identified using the model. The relative security of these water resources will also be identified. Overuse of a depleted water source will have consequences for all connected systems. Planning to access resources with capacity would be wise and achievable in this analysis. Also, contaminated water disposal can be influenced to protect sensitive water supplies.

Appendix II

Uncertainties

There are some underlying uncertainties existing that pose a threat to the utilization of the suggested model. The largest of these is the quality of the climatic and geological data. Climatic variability must be understood to define the zones where P>Et and where P<Et. Further work needs to be done to create accurate climate maps that can guide Al-Pac activities. Especially at the current scale (1:2,000,000) the geological data is of little value to planning a road or cutblock. It is not practical for Al-Pac to conduct geology surveys in all our harvest blocks. Indicators of forest soils/geology may be an option using AVI and existing geology data combined.

These uncertainties will be “show stoppers” and are targeted as next steps in the Boreal Conservation Plan Science Team’s priorities.

Literature cited:

Alberta-Pacific Forest Management Area Operating Ground Rules, 2000

Buttle JM, Creed IF, Moore D. 2005. Advances in Canadian forest hydrology, 1999-2003. *Hydrological Processes,* **19**: 169-200

Devito et al 2005a, “A framework for broad scale classification of hydrologic response units on the Boreal Plain: Is topography the last thing to consider?” Hydrologic Processes, 16 March 2005.

Devito KJ, Creed IF, Fraser C. 2005b. Controls on runoff from a partially harvested aspen forested headwater catchment, Boreal Plain, Canada. *Hydrological Processes,* **19**: 3-25.

Winter TC. 2001. The concept of hydrologic landscapes. *J. Am. Water Resour. Assoc.,* **37**: 335-349.

HYDROLOGIC EFFECTS OF FOREST HARVESTING IN THE ALBERTA-PACIFIC FOREST INDUSTRIES FOREST MANAGEMENT AREA

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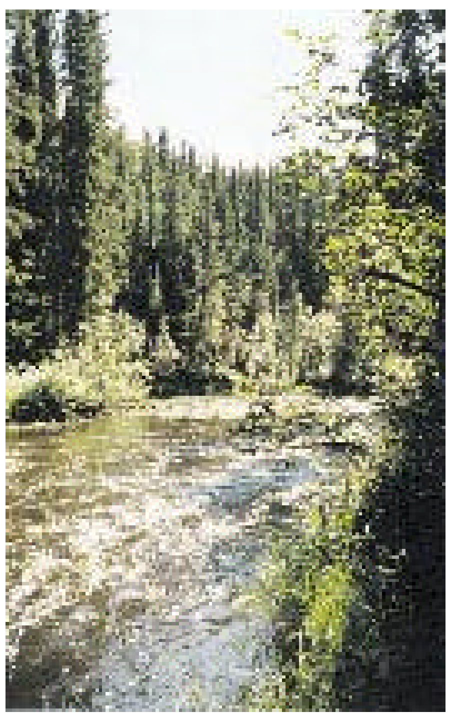
April 2004



Executive Summary

The hydrologic effects of forest harvesting in the Alberta-Pacific Forest Industry's Inc.'s (Alpac) Forest Management Area (FMA) was simulated using the ECA-Alberta hydrologic model (Silins, 2000). The objectives of this analysis were to estimate changes in mean annual streamflow, Equivalent Clear-Cut Area (ECA), and the time for hydrologic recovery for the 11 Forest Management Units (FMU) in the Alpac's FMA.

The focus of this analysis was to evaluate the hydrologic effects of harvesting operations at a strategic level (large scale) within the Alpac FMA. Analysis was conducted at the FMU (11 total) and the FMA scale by simulating the effect of applying the proposed annual allowable cuts (AAC) by species as an even flow harvest rate in each management unit.

Changes in streamflow were simulated based on the area harvested (determined from AAC) in each of 11 FMUs and over the entire FMA, rate of forest re-growth (based on provincial average yield curves for unmanaged stands), and long-term average climatic conditions specific to each management unit. To evaluate the effect of an even-flow harvesting scenario (area based) and illustrate the rate of hydrologic recovery of this landscape (re-establishment of landscape level forest water use), simulations were projected for 100 years (50 years of harvesting at the proposed harvest rate indicated by the AAC, followed by 50 years of no harvesting) based on average precipitation and streamflow conditions in the region.

- ECA-Alberta simulations of even-flow harvest in the region predict increases in mean annual water yield (streamflow) during the 1st 35-50 yrs after which no further increases in streamflow are observed because the rate of harvest is balanced by the rate of hydrologic recovery of stands harvested earlier in the scenario, followed by a decline in wateryield with simulated suspension of harvesting activities:
    - A maximum increase in average annual water yield of 2.4mm or 2.86% occurred from 2046 to 2055 for the FMA.
    - ECA for the FMA peaked at 3.13%, from years 2053 to 2055.
    - Hydrologic recovery for the FMA (the time for increased water yields to approach zero upon suspension of harvesting) was 39 years.
- Some variability in projected increases in average annual water yield following harvesting was projected in individual FMU's:
    - Maximum increases in water yield ranged from 1.45% in A14 to 6.06% in S11
    - 8 of the 11 units had projected water yield increases of less than 4%.
    - Smaller FMU's experienced the largest simulated yield increases.
    - ECA for the FMUs ranged from 2.54% in L11 to 4.48% in S11.
    - 8 of the 11 units had ECAs less than 4%.
    - Hydrologic recovery for each of the FMU's was variable and ranged from 35 to 42 years.

The results from this analysis indicate that projected increases in annual yield and ECA at large landscape scales (FMU/FMA) are quite low when considered against the natural range of variation in steamflow produced by fluctuation in annual climate in the region. Based on the scale of this analysis (FMU/FMA) and the assumption of an even spatial distribution of harvest, the projected increases in average annual yield are probably not significant and are likely below

the measurement detection limit using standard hydrometric techniques. However, actual water yield increases will probably be larger than simulated in this analysis if harvesting effects were evaluated at a smaller scales (township or catchment scale). It should also be noted that the ECA-Alberta model projects average streamflow changes over time assuming average climatic conditions. While this allows for the evaluation of the incremental hydrologic effects of forest disturbance over and above that produced by climatic variation, it is important to note that actual water yield increases produced by disturbance co-vary strongly with variation in annual climate. Streamflow increases in wet years may be significantly higher than those presented here. Conversely, actual yield increases in dry years may be significantly less or non-existent. The ECA model also predicts changes in annual yield based on average provincial rates of stand growth. Therefore, actual stand growth and regeneration lags will affect actual yield increases and ECA's.

Disclaimer

The assessment of the hydrologic impacts of harvesting presented in this report reflects the output from a hydrologic simulation model and does not necessarily reflect the actual impacts that may be observed. Though the representativeness of output from ECA-Alberta has been evaluated in parallel simulations with other widely adopted forest management oriented hydrologic models (U.S. EPA WRENSS) by Dr. U. Silins (Dept. of Renewable Resources, University of Alberta) and shows robust and favorable agreement with these other models, ultimately, the reliability of estimates produced using this and other similar models depends on availability of representative climatic/hydrometric data, representativeness of regional forest growth characteristics with Alberta provincial average forest growth and yield data, and representative forest harvesting plans. In this context, the author has prepared and evaluated the hydrometric/climatic data used in this analysis and considers these data to be a reliable reflection of hydrologic conditions for this analysis. Limitations or errors due to deviation in actual forest growth rate from provincial average growth rates or limitations imposed by spatial/temporal scale of analysis are outside the author's control. In particular, the spatial distribution of harvested blocks, as well as the presence of additional disturbances (fire, insects, etc.) will also affect water yields. Actual harvest levels in individual townships may deviate significantly from the approach adopted here. As hydrologic effects will likely closely reflect the actual timing and area harvested by stand type within regions, the hydrologic effects simulated in this report may not reflect the actual harvest within FMU's.

Furthermore, it should also be re-emphasized that the ECA-Alberta model projects average annual streamflow changes over time assuming average climatic/hydrologic conditions in the region and the rate of stand regeneration. Therefore, changes in annual water yield due to disturbance will vary from simulations based on the actual variability in climate and the degree of departure from average climatic conditions.

Brendan Brabender

Dr. Uldis Silins

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Hydrologic Effects of Forest Harvesting in the Alpac Inc. FMA

The objectives of this report are to assess the effects of even flow (area based) timber harvesting in the Alpac FMA, and in each of its' FMUs on average annual streamflows, Equivalent Clear Cut Area, and to estimate the time for hydrologic recovery (i.e. the time for increased streamflows to disappear following cessation of harvest).

Methods

The hydrologic effects of forest harvesting were simulated using the Equivalent Clearcut Area-Alberta (ECA-Alberta) (Silins, 2000) hydrologic model, which provides an estimate of changes in average annual streamflows. Changes in streamflows are based on the area harvested in a watershed, rate of forest regrowth and water balance calculations of generated runoff (determined from long term monthly precipitation and annual streamflows).

ECA refers to "equivalent clear-cut area" which describes the current "effective" area that an old or recovering disturbance (e.g. clear cuts, burns, insect defoliation or extensive disease mortality) represent in terms of hydrologic effects. The concept can be used to express the partial state of recovery from disturbance of individual forest stands, or the cumulative effect of multiple disturbances across large landscapes (net effect of multiple disturbances at different stages of ecological recovery) over long periods of time. In addition to an estimate of the ECA or partial state of hydrologic recovery of individual disturbances or entire watersheds, the technique can also be used to predict changes to annual water yield relative to baseline annual streamflows. The main application of the model is to evaluate the effect of past disturbances on streamflow in a watershed, and to project the cumulative effect (net combined effect) of both past and proposed future forest harvesting and/or natural disturbances on streamflow.

Equivalent Clearcut Area procedures were originally developed in the early 1970's in Idaho by a group of hydrologists with the USDA Forest Service (Silvey et al., 1973). Initially, the ECA model was conceived of as a means of estimating the hydrologic impact of additional forest harvesting in watersheds where previous harvesting or other land disturbances had already occurred. The objective was not to produce a detailed, highly accurate simulation of streamflow, but rather a projection of streamflow changes over time assuming average climatic conditions in the region. However, data on hydrologic recovery was very limited in the early 1970's and this limitation along with criticisms concerning procedures by which hydrologic impacts were assessed (i.e. the model was not well founded on hydrologic theory) led several researchers to subsequently criticize the procedure (Belt 1980, King 1989, Reid 1993). Despite these limitations, the ECA technique has been used as a cumulative effects assessment tool in several jurisdictions both in the U.S (Reid 1993) and Canada (B.C. Forest Practices Code).

Overall, the ECA-Alberta model provides a relatively simple framework for evaluation of hydrologic effects of forest practices with more modest input data requirements. However, the accuracy of the model output depends primarily on accurate information on hydrologic recovery of forest stands after disturbance, and availability of representative regional streamflow and precipitation data.

Data Requirements

Data required for ECA-Alberta represent a sub-set of the overall data requirements for the more detailed WRENSS procedure (Swanson, 2000) (Table 1).

Table 1 Data Requirements for the ECA Procedure

Current and Regenerating Species	Any phase III species code is acceptable but all simulations are based on provincial average yield classes for unmanaged stands (0/0 utilization standard) for pine, white spruce, black spruce and deciduous stands
Block Area in Hectares	Area of harvested unit in hectares
Year of Harvest	The year the unit was cut in yyyy format.
Site Quality	Site quality code corresponding to median site index described in provincial yield tables. Acceptable codes are G (good), M (med), and F (fair).
Watershed Area	The total size of the unit in hectares (Watershed, FMU, or FMA)
Average Annual Streamflow (mm)	Expressed in area mm
Average Annual Precipitation (mm)	Expressed in area mm

The purpose of this analysis was to evaluate the hydrologic effects of harvesting operations at a strategic level (large spatial and temporal scale). Each FMU was designated as a watershed unit. The harvest scenario consisted of applying a constant annual harvest area by species based on the annual allowable cut (AAC) for each each FMU. Since the ECA model does not simulate water balance of mixedwood stands, these cover classes were represented as pure deciduous or conifer stands for simulation purposes. The D, CD, and DC cover classes were changed to Aw, Sw, and Aw respectively. In addition, since data on specific stand polygons or cutblocks was not available, a medium site productivity class was assumed for all areas. The AAC (m^3/ha/year) was converted into the number of hectares required to capture that volume each year (Table 2), and the area based AAC (ha) in each cover class was simulated for each year.

Table 2 Annual Allowable Cuts (AAC) (ha) by Cover Class and FMU

FMU	D (Aw)	Sw	Pj	Sb	DC (Aw)	CD (Sw)
L1	752.90	101.426	332.71	28.192	236.59	84.442
L2	769.22	182.934	94.97	48.434	176.53	109.306
L3	433.53	370.94	102.30	89.81	240.98	191.756
L8	300.82	59.426	32.57	9.354	42.71	38.564
L11	1,754.13	142.264	868.78	121.546	414.23	172.016
S7	525.98	38.36	51.62	16.656	70.68	36.516
S11	1,083.07	124.602	347.77	37.426	202.75	111.802
S18	1,343.28	288.85	120.61	39.5	496.13	236.25
S22	2,139.24	173.668	431.58	29.762	340.88	199.388
A14	1,171.27	478.26	788.42	134.534	474.93	200.84
A15	2134.95	549.40	1,037.92	44.86	394.34	413.98
TOTAL	**12,408.38**	**2,510.13**	**4,209.24**	**600.07**	**3,090.75**	**1,794.86**

Therefore, the same harvest area in each of the cover classes was simulated for every year (even-flow on an area basis) in each FMU. For example, 989.49 ha of Aw, 185.87 ha of Sw, 332.71 ha of Pj, and 28.19 ha of Sb were harvested every year in FMU L1. The FMA scale scenario was simulated as the sum of all harvests in individual FMUs. This harvesting pattern was simulated for 50 years to simulate the initial and steady-state hydrologic effects of applying even-flow harvest in the region. A subsequent period of 50 years with no harvesting was also simulated to illustrate the rate of hydrologic recovery of disturbances in this region.

Streamflow and precipitation data were obtained from Water Survey of Canada, Environment Canada, and the Alberta Land and Forest Service for each of the 11 FMUs (Appendix 1). Although streamflow/climate data was generally available for most regions within the FMA, some stations from outside the FMA were used to represent streamflow and precipitation for individual FMUs.

The ECA model uses two approaches to estimate the rate of hydrologic recovery of regenerating stands after disturbance, 1) based on the rate of basal area growth, and 2) based on the rate of annual volume growth. Both procedures utilize LFS provincial average growth/yield data for unmanaged (fire origin) stands. The volume growth function generally simulates a more rapid hydrologic recovery than the basal area function and does not require the user to specify an age at full hydrologic utilization for each species. With this option, hydrologic recovery is predicted based on the close relationship between volume growth and stand level leaf area index (LAI) (Long and Smith, 1992; and Kollenberg and O'Hara, 1999). Recent work by Brabender and Silins (2004), has confirmed that there is a strong relationship between annual volume growth and LAI for lodgepole pine in Alberta. As a result, this analysis uses the rate of annual volume growth to predict the rate of hydrologic recovery up to full (100%) hydrologic recovery which is assumed to occur at the time (age) of maximum stand LAI for any given species.

The ECA procedure also includes the option to include a regeneration lag when running simulations. This gives the user additional flexibility to adjust hydrologic recovery curves to simulate stand regeneration success and early growth in their region. This feature can also be used to explore what-if scenarios for silvicultural and harvesting strategies. The regeneration lag will delay the start of hydrologic recovery (i.e. hydrologic recovery will be zero) for the indicated number of years for each affected stand. Entering a negative value will shorten the recovery period by the specified time in years (i.e. opposite effect as described above). This can be used to simulate hydrologic recovery of stands with significant advanced growth or dedicated understory protection cuts. The mean age of the understory should be known or estimated to input the correct value for a negative regeneration lag.

Since this analysis was intended as a strategic analysis based on broad FMU harvest levels for several stand types (from AAC) rather than from tactical level harvest plans (i.e. detailed block information was not available), the regeneration lag was assumed to be 0yrs. However, it should be noted that the rate of actual hydrologic recovery will vary based on the success/failure of regenerating harvested stands.

Results

Hydrologic simulation of forest harvesting showed a maximum increase in annual water yield of 2.4mm, or 2.86% in years 2046 to 2055 (Appendix 2). The ECA followed a similar pattern to that of annual yield, and peaked at 3.13%, from years 2053 to 2055 (Table 3). Increased water yields decreased rapidly after simulated cessation of harvest and concurrent regeneration of harvested blocks and the hydrologic recovery for the FMA (the time for increased water yields to approach zero) was 39 years.

Table 3 Projected increases in ECA and Annual Yield for each FMU and the entire FMA

FMU	Area (ha)	Maximum ECA %	Maximum Yield Increase %
S11	332,548	4.48%	6.06%
S22	803,548	3.02%	3.97%
A15	1,436,492	2.94%	2.29%
L2	300,539	4.27%	4.20%
L8	126,136	3.40%	3.38%
L1	333,601	3.61%	3.32%
L11	1,047,674	2.54%	2.41%
A14	1,173,943	2.71%	1.45%
L3	587,387	3.13%	1.96%
S7	122,021	4.37%	4.55%
S18	602,461	3.71%	3.16%
FMA	6,866,350	3.13%	2.86%

Hydrologic simulations for the 11 FMU's resulted in projected maximum annual water yield increases between 1.45% in A14 to 6.06% in S11, however 8 of the 11 units had projected increases of less than 4%. In general, the smaller FMU's experienced the largest simulated yield increases. The projected ECA's for the FMU's ranged from 2.54% in L11 to 4.48% in S11, with 8 of the 11 units having ECA's less than 4%.

Applying a constant harvest rate to the landbase resulted in a rapid increase in both ECA and projected annual yields during the first 10 years following the commencement of harvesting. Then as stands harvested early in the scenario enter the rapid juvenile growth phase, ECA and annual water yield gradually reach a plateau by year 2054. Hydrologic recovery for each of the FMU's was variable and ranged from 35-42 years (Appendix 2).

Summary and Conclusions

The analysis of hydrologic effects of area based even-flow harvesting on the Alpac FMA simulated by ECA-Alberta indicate the following: Increases in mean annual water yield (streamflow) during the 1st 35-50 years after which no further increases in streamflow were observed because the rate of harvest is balanced by the rate of hydrologic recovery of stands harvested earlier in the scenario (i.e. rate of disturbance and rate of hydrologic recovery are at a balanced steady-state by this point). Simulations predict decline in average annual water yield with simulated suspension of harvesting activities

- Hydrologic simulation of harvesting in the Alpac FMA indicated increases in average annual water yield following harvesting.
    - The maximum increase in average annual water yield of 2.4 mm or 2.86% occurred between 2046 and 2055.
    - The maximum ECA increase of 3.13% occurred between 2053 and 2055

- Hydrologic simulations in the 11 FMU's showed increases in annual water yield.
    - Average water yield increases ranged from 1.45% to 6.06%.
    - Average water yield increases were largest in FMUs with the greatest percent area harvested, however climatic conditions and baseline annual yield also play an important role in determining the magnitude of hydrologic changes.
    - Maximum ECA % increases ranged from 2.54% to 4.48% over the 50 year harvesting scenario.

- Hydrologic recovery following harvesting was relatively rapid across the FMA.
    - Upon simulated suspension of harvesting, hydrologic recovery across the FMA was approximately 39 years.
    - Hydrologic recovery in the 11 FMU's ranged from 35 to 42 years.

The results from this analysis indicate that projected increases in annual yield and ECA at large landscape scales (FMU/FMA) are quite low when considered against the natural range of variation in steamflow produced by fluctuation in annual climate in the region. Based on the scale of this analysis (FMU/FMA) and the assumption of an even spatial distribution of harvest, the projected increases in average annual yield are probably not significant and are likely below the measurement detection limit using standard hydrometric techniques.

However, it is important to note that the hydrologic effects of disturbance simulated in this analysis reflect effects that are likely at a very large scale. The effects of harvesting on streamflow (average annual yield) will probably be larger than simulated here when evaluated at smaller scales (township or catchment scales). Furthermore, as actual harvest levels in individual townships or the temporal distribution of disturbances deviate significantly from the approach adopted here (i.e. an AAC (ha) applied to a FMU) the actual hydrologic effects may differ from those simulated here as these hydrologic effects reflect the actual timing and area harvested by stand type within a catchment, township, or region, The timing of the actual harvest entries, in particular, may differ considerably from that simulated here.

It should also be noted that the ECA-Alberta model projects average streamflow changes over time assuming average climatic conditions. While this allows for the evaluation of the incremental hydrologic effects of forest disturbance over and above that produced by climatic variation, it is important to note that actual water yield increases produced by disturbance co-vary strongly with variation in annual climate. Streamflow increases in wet years may be significantly higher than those presented here. Conversely, actual yield increases in dry years may be significantly less or non-existent. The ECA model also predicts changes in annual yield based on average provincial rates of stand growth. Therefore, deviation of actual stand growth and regeneration from provincial average yield curves will affect simulation of ECAs and projected average annual streamflow.

On-going hydrologic research in Alpac's Boreal Conservation Program will improve the reliability and representativeness of hydrologic analysis in this region. Research lead by Dr. K. Devito (HEAD project) has provided valuable insights into forest water balance of this region. In particular, the dominant role of evapotranspiration and annual changes in soil moisture storage are key factors governing hydrologic behavior of this region. While this strongly supports the use of management models based on disturbance effects on evapotranspiration (ECA-Alberta and WRENSS), this work has also raised important questions about usefulness of using topographically defined watershed boundaries to define hydrologically meaningful landscape units in this region. New research proposed by the Western Boreal Forest Hydro-biogeochemistry Group at the University of Alberta will help refine region specific understanding of the role of disturbance on water and water reliant resources.

The use of hydrologic analysis such as that undertaken in this report could also be improved with further research into how regional variation in climate and hydrology in forested regions of the province from the Rocky Mountains through upper/lower foothills, and boreal plain regions is related to regional differences in acceptable harvest levels from a water resources perspective. As it is highly unlikely that a similar forest disturbance magnitude is likely to cause similar hydrologic effects across this hydrologic gradient (i.e. the 15% streamflow increase threshold suggested by AB ENV in one foothills region), research that illustrates appropriate disturbance thresholds needs to be conducted across the forested regions of the province if models such as WRENSS or ECA-Alberta are to be more commonly used by the forest sector in Alberta (industry and government).

Literature Cited

Belt, G.H., 1980, Predicting streamflow changes caused by forest practices using the equivalent clearcut area model. Univ. Idaho, Forest, Wildlife and Range Exp. Stn., Bull. No. 32.Silvey,

Brabender, B, and Silins, U., 2004. Interception Dynamics of Lodgepole pine. Poster presentation. Canadian Geophysical Union, Annual Scientific Meeting. May 17-21, 2004, Montreal, Canada.

Haupt, H.L., H.F., Megahan, W., Garn, H.S., Pfankuch, D., Delk, R., Harnish, C., Rosgen, D., Galbraith, A., Russell, B., and Isaacson, A. 1973. Forest Hydrology; hydrologic effects.

Kollenberg, C.L., and O'Hara, K.L., 1999. Leaf area and tree increment dynamics of even-aged and multiaged lodgepole pine stands in Montana. Can. J. For. Res. 29 (6): 687-695.

Long, J.N, and Smith F.W., 1992. Volume increment in *Pinus contorta var. latifolia*: The influence of stand development and crown dynamics. For Ecol. Mgmt. 53 (1-4): 53-64.

King, J.G., 1989, Streamflow responses to road building and harvesting: a comparison with the equivalent clearcut area procedure. U.S.D.A. For. Serv., Int. Mtn. Res. Stn., Res. Paper INT-401

Reid, L.M., 1993, Research and cumulative watershed effects, U.S.D.A. For. Serv., Pacific S.W. Res. Stn., Gen. Tech. Rpt. PSW-GTR-141of vegetation manipulation, Part II, U.S.D.A. Forest Serv., Div. Nat. Res., Northern Region.

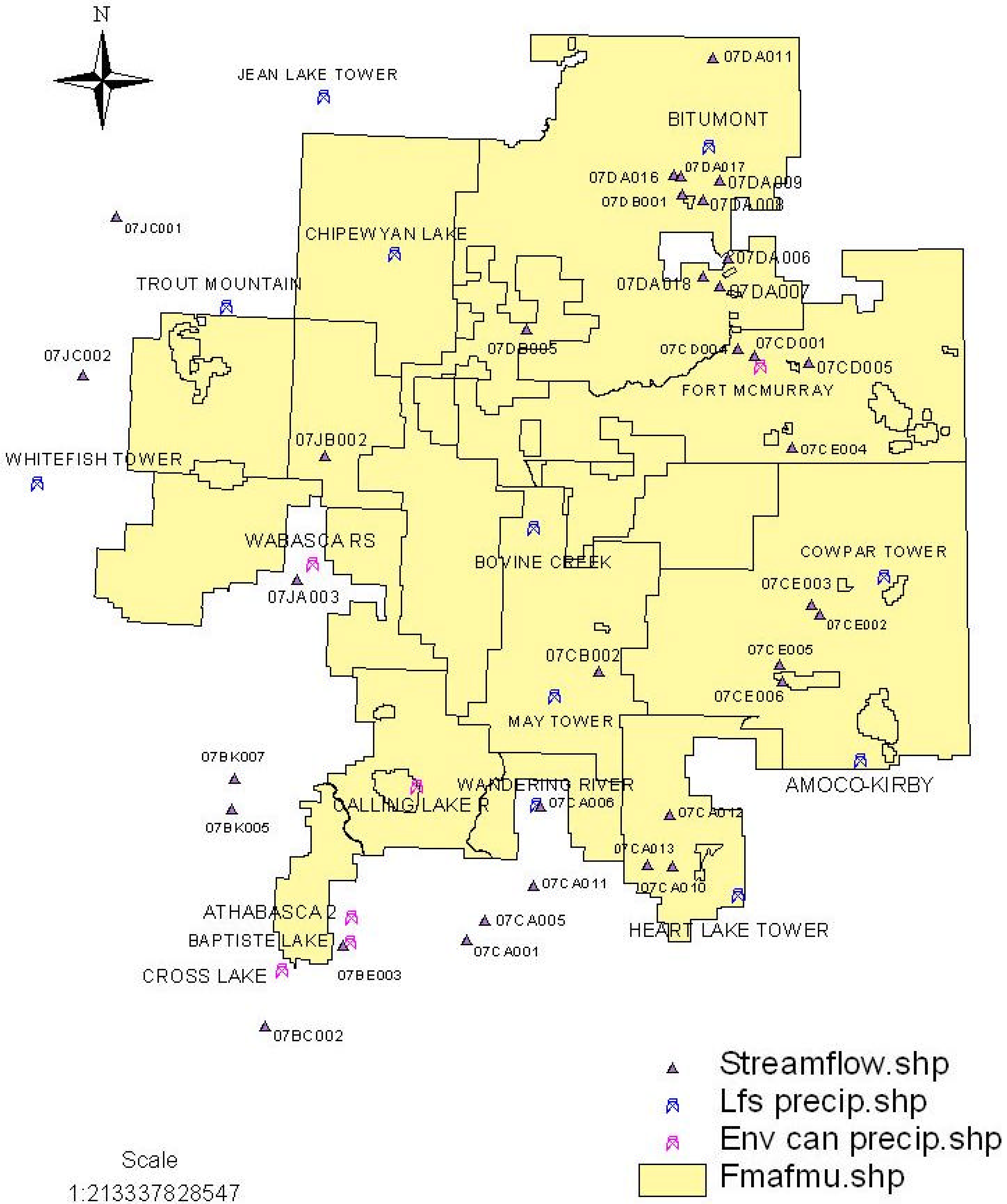
Silins, U., 2000, ECA-Alberta - Cumulative Watershed Disturbance & Hydrologic Recovery Simulator. Dept. Renewable Resources, 751-GSB, University of Alberta, Edmonton. Canada, T6G 2H1, (uldis.silins@ualberta.ca).

Silvey, H.L., Haupt, H.F., Megahan, W., Garn, H.S., Pfankuch, D., Delk, R., Harnish, C., Rosgen, D., Galbraith, A., Russell, B., Isaacson, A., 1973, Forest Hydrology; hydrologic effects of vegetation manipulation, Part II, U.S.D.A. Forest Serv., Div. Nat. Res., Northern Region.

Swanson R. H. 2000. WrnsSdr User’s Manual, Using and applying the USEPA WRENSS, hydrologic procedures for all snow dominated regions of Canada. Peak flow analyses applicable to the Athabasca, North and South Saskatchewan River Watersheds of Western Alberta. Version 1.021. R. H. Swanson Hydrology Consultant, # 28 216 Three Sisters Drive, Canmore, Alberta, Canada.

Appendix 1

Precipitation and Streamflow Gaging Stations for Alpac's FMA

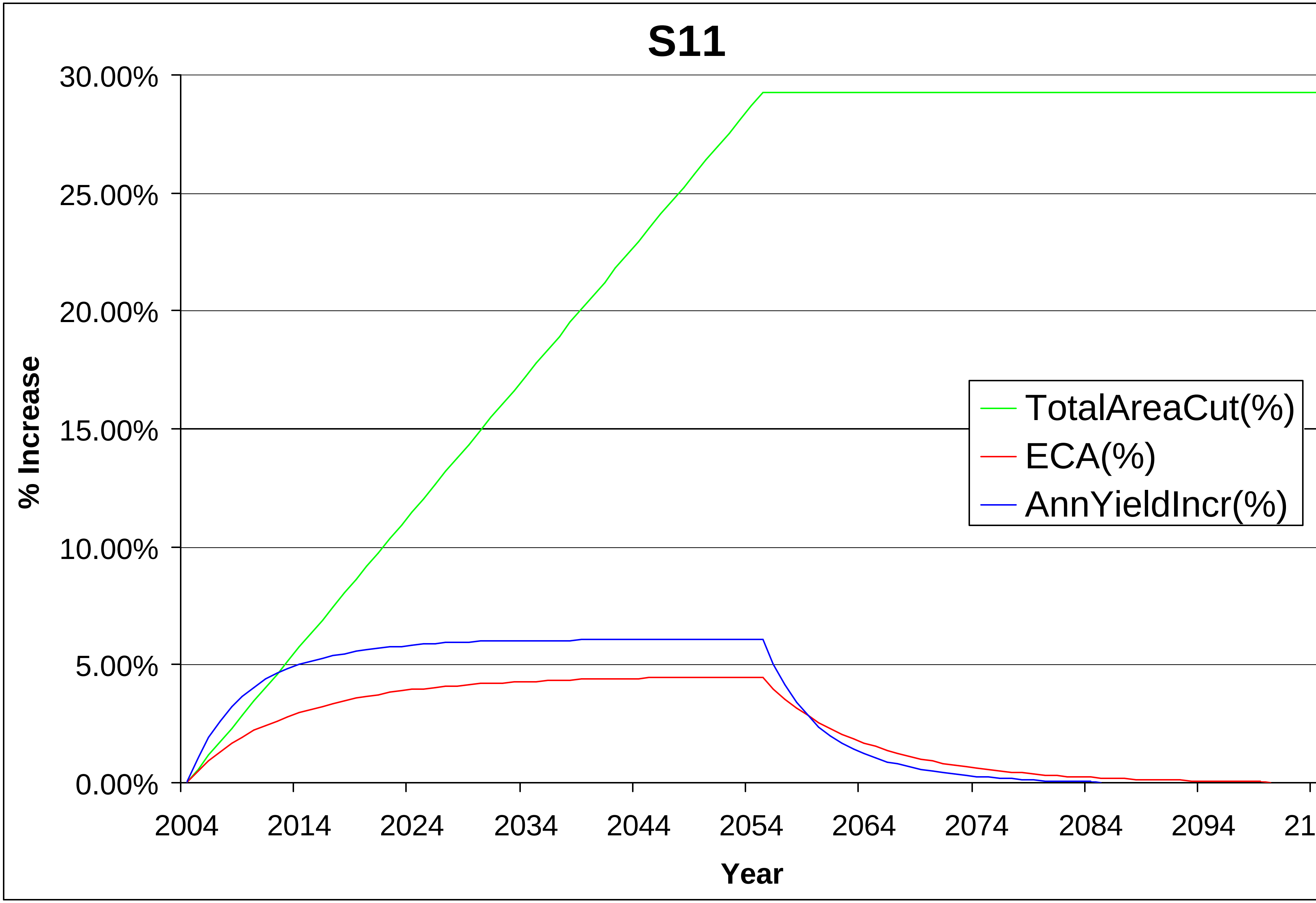


Summary of Climate and Streamflow Data Used in the Analysis

	Streamflow				Precipitation	
FMU	Stn Name	Year Round*	Years in record	Annual Yield (mm)	Stn Name	Annual Precip (mm)
S11	07JC001	N	26	59.79	Trout Mountain	529
S11	07JC002	N	14	72.37	Whitefish Tower	449
S11	07JB002	Y	11	52.87	Wabasca RS	475
S22	07JC001	N	26	59.79	Chipewyan Lake	386
S22	07JB002	Y	11	52.87	Trout Mountain	529
S22	07DB005	N	9	75.85	Jean Lake Tower	518
S22					Wabasca RS	475
A15	07DA016	Y	19	76.08	Bitumont	493
A15	07DA017	Y	12	92.95	Chipewyan Lake	386
A15	07DA009	Y	19	98.88	Fort McMurray	456
A15	07DB001	Y	29	84.93	Bovine Creek	412
A15	07DA008	Y	27	88.49		
A15	07DB005	N	9	75.85		
A15	07DA006	Y	29	120.49		
A15	07DA018	Y	26	104.18		
A15	07DA011	Y	19	49.0		
L2	07CA006	Y	30	93.51	Calling Lake	454
L2	07CA005	N	35	50.75	Athabasca 2	502
L2	07CA001	N	12	66.1	Wandering River	420
L2	07CA003	N	34	83.34	May Tower	539
L2	07BK007	Y	33	108.67		
L8	07CA006	Y	30	93.51	Heart Lake Tower	517
L8	07CA012	N	17	109.05	May Tower	539
L8	07CA011	Y	14	20.65	Calling Lake	454
L8	07CA005	N	35	50.75	Wandering River	420
L8	07CA013	N	17	49.79		
L1	07CA006	Y	30	93.51	Heart Lake Tower	517
L1	07CA012	N	17	109.05	May Tower	539
L1	07CA013	N	17	49.79	Ampco-Kirby	420
L1					Wandering River	420
L11	07CE003	N	19	84.27	May Tower	539
L11	07CE002	N	19	89.48	Ampco-Kirby	420
L11	07CE005	N	14	53.1	Cowpar Tower	433
L11	07CE006	N	12	67.17	Bovine Creek	412
L11	07CE004	N	14	96.2		
A14	07CE004	N	14	96.2	Fort McMurray	456
A14	07CD005	Y	35	139.62	Cowpar Tower	433
A14	07CD001	Y	47	122.29	Bovine Creek	412
A14	07CD004	Y	36	122.29	Bitumont	493
L3	07CA006	Y	30	93.51	Bovine Creek	412
L3	07CB002	N	19	120.89	May Tower	539
L3	07CA012	N	17	109.05	Calling Lake	454
L3					Wandering River	420
S7	07BE003	N	21	52.28	Cross Lake	549
S7	07BC002	Y	44	86.66	Athabasca 2	504
S7	07BK005	N	37	106.85	Baptiste	467
S18	07JB002	Y	11	52.87	Wabasca RS	475
S18	07JA003	N	16	126.53	Whitefish Tower	449
S18	07JC002	N	14	72.37	Bovine Creek	412

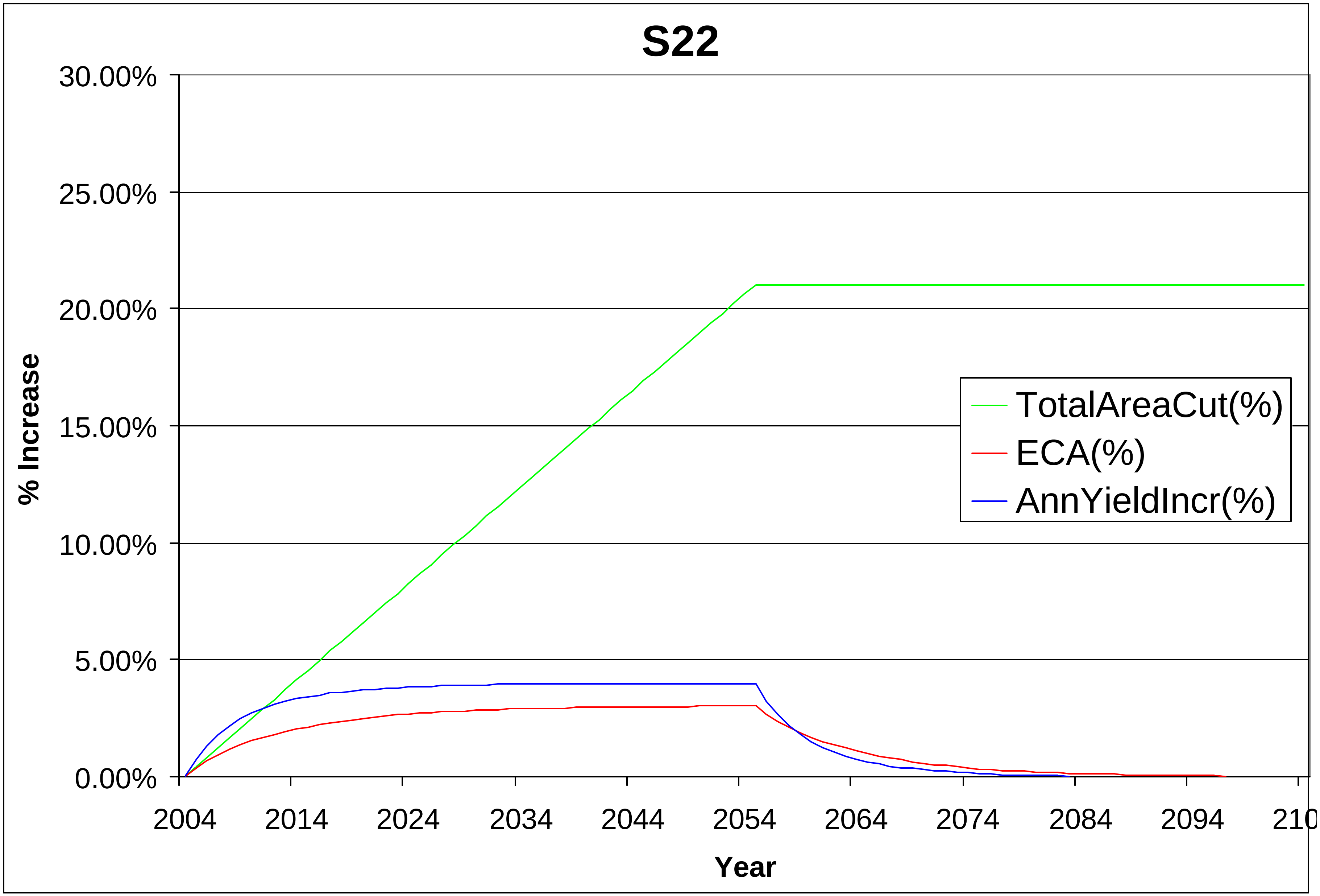
* Indicates if streamflow measurements were taken during the winter months

Appendix 2: ECA-Alberta Model Outputs

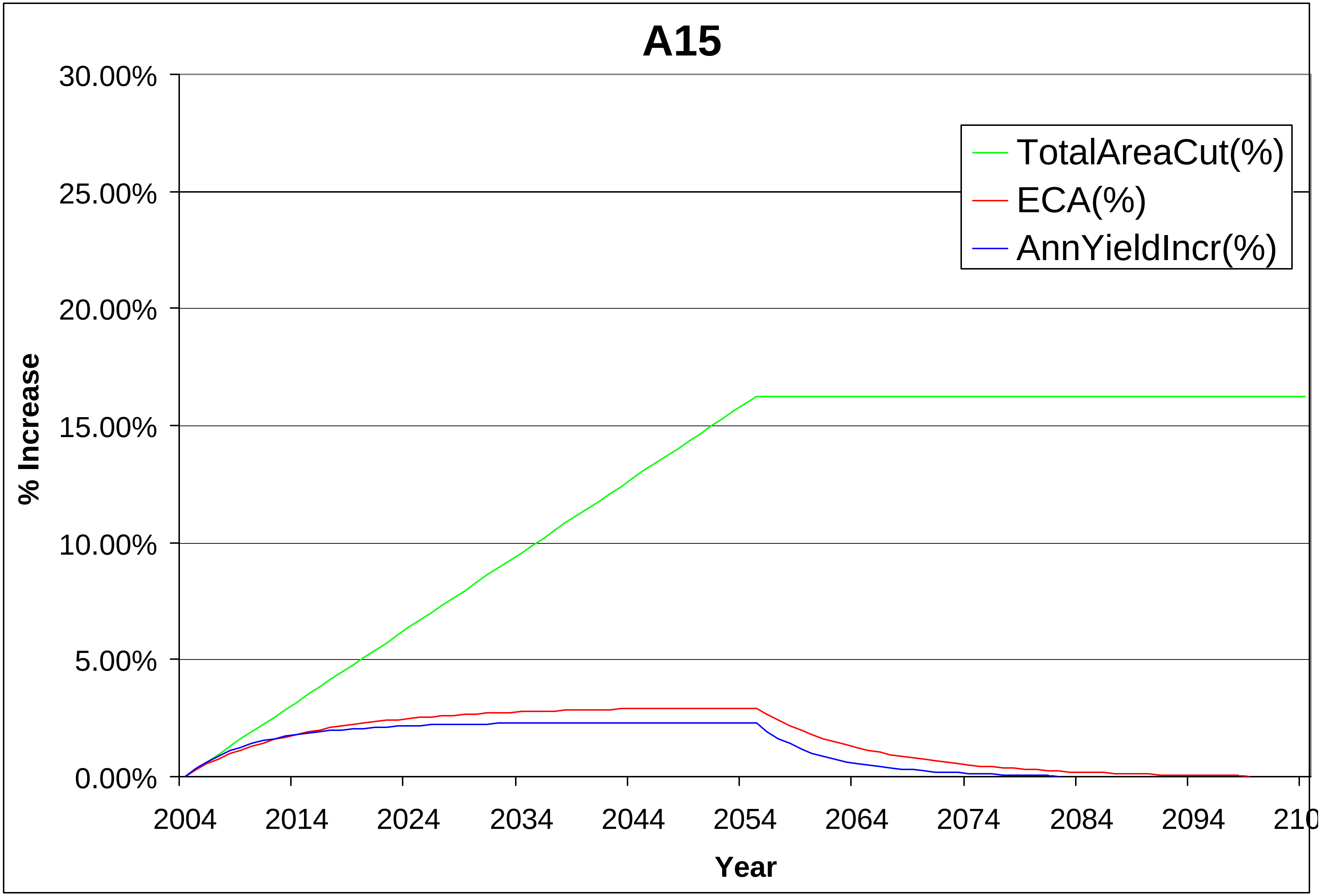


S11
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

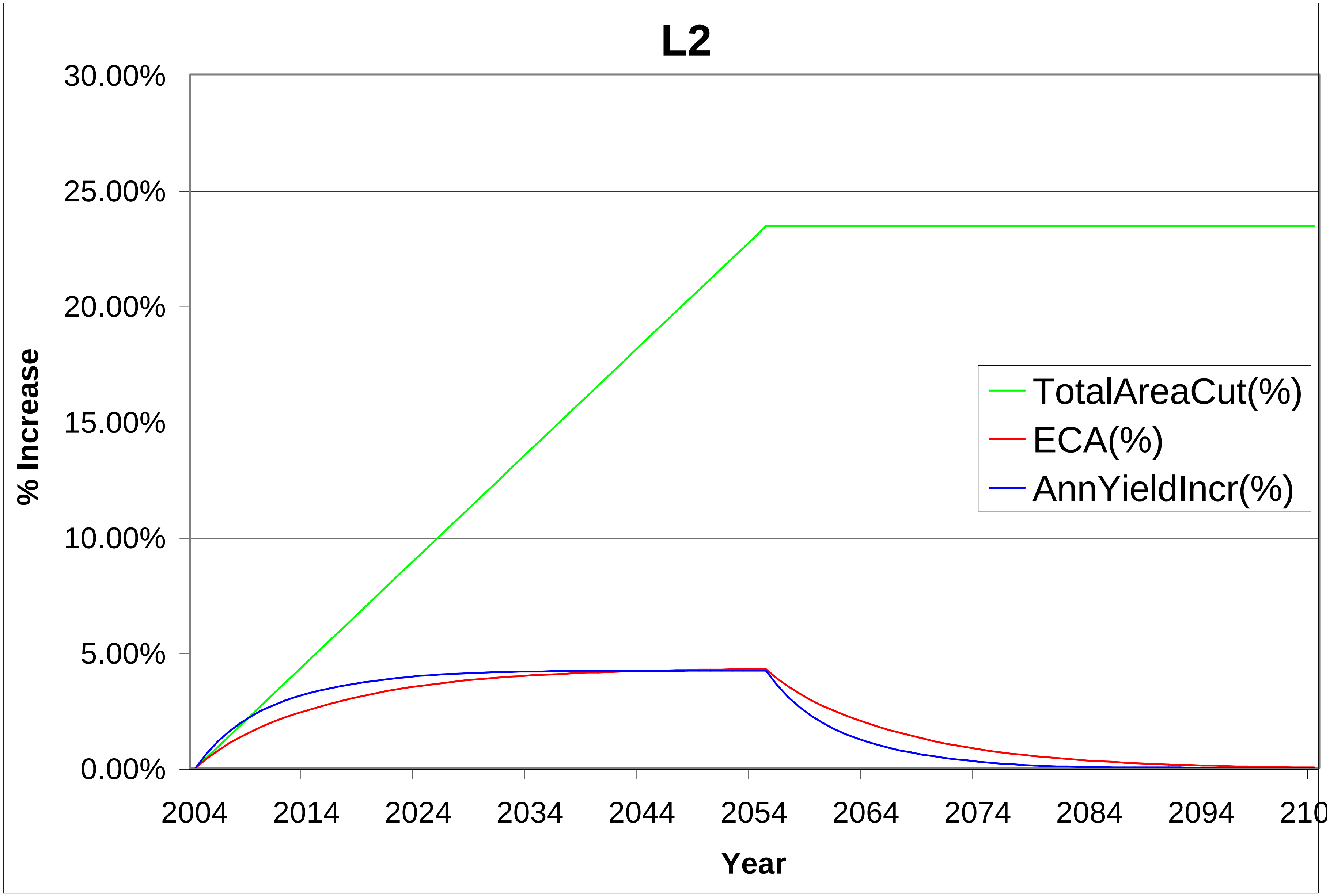
S11						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	1907.4	1663.9	0.57%	0.50%	1.06%	0.7
2006	3814.8	3115.6	1.15%	0.94%	1.93%	1.2
2007	5722.3	4383.2	1.72%	1.32%	2.63%	1.6
2008	7629.7	5491.9	2.29%	1.65%	3.21%	2.0
2009	9537.1	6463.9	2.87%	1.94%	3.68%	2.3
2010	11444.5	7319.0	3.44%	2.20%	4.06%	2.5
2011	13351.9	8074.4	4.02%	2.43%	4.37%	2.7
2012	15259.4	8744.9	4.59%	2.63%	4.63%	2.9
2013	17166.8	9343.4	5.16%	2.81%	4.84%	3.0
2014	19074.2	9880.6	5.74%	2.97%	5.02%	3.1
2015	20981.6	10365.6	6.31%	3.12%	5.16%	3.2
2016	22889.0	10805.8	6.88%	3.25%	5.29%	3.3
2017	24796.5	11206.9	7.46%	3.37%	5.39%	3.3
2018	26703.9	11573.8	8.03%	3.48%	5.48%	3.4
2019	28611.3	11903.2	8.60%	3.58%	5.56%	3.4
2020	30518.7	12198.4	9.18%	3.67%	5.63%	3.5
2021	32426.1	12463.6	9.75%	3.75%	5.69%	3.5
2022	34333.6	12702.1	10.32%	3.82%	5.74%	3.6
2023	36241.0	12916.5	10.90%	3.88%	5.79%	3.6
2024	38148.4	13108.9	11.47%	3.94%	5.83%	3.6
2025	40055.8	13281.2	12.05%	3.99%	5.87%	3.6
2026	41963.2	13435.6	12.62%	4.04%	5.90%	3.7
2027	43870.7	13574.8	13.19%	4.08%	5.93%	3.7
2028	45778.1	13700.6	13.77%	4.12%	5.95%	3.7
2029	47685.5	13814.7	14.34%	4.15%	5.97%	3.7
2030	49592.9	13918.2	14.91%	4.19%	5.99%	3.7
2031	51500.3	14012.4	15.49%	4.21%	6.00%	3.7
2032	53407.8	14098.4	16.06%	4.24%	6.01%	3.7
2033	55315.2	14177.9	16.63%	4.26%	6.02%	3.7
2034	57222.6	14251.2	17.21%	4.29%	6.03%	3.7
2035	59130.0	14318.8	17.78%	4.31%	6.03%	3.7
2036	61037.4	14380.9	18.35%	4.32%	6.04%	3.7
2037	62944.9	14437.7	18.93%	4.34%	6.04%	3.7
2038	64852.3	14489.7	19.50%	4.36%	6.04%	3.7
2039	66759.7	14537.0	20.08%	4.37%	6.05%	3.7
2040	68667.1	14579.9	20.65%	4.38%	6.05%	3.7
2041	70574.5	14618.9	21.22%	4.40%	6.05%	3.8
2042	72482.0	14654.1	21.80%	4.41%	6.05%	3.8
2043	74389.4	14685.9	22.37%	4.42%	6.05%	3.8
2044	76296.8	14714.6	22.94%	4.42%	6.05%	3.8
2045	78204.2	14740.4	23.52%	4.43%	6.05%	3.8
2046	80111.6	14767.9	24.09%	4.44%	**6.06%**	3.8
2047	82019.1	14792.9	24.66%	4.45%	**6.06%**	3.8
2048	83926.5	14815.5	25.24%	4.46%	**6.06%**	3.8
2049	85833.9	14835.8	25.81%	4.46%	**6.06%**	3.8
2050	87741.3	14853.9	26.38%	4.47%	**6.06%**	3.8
2051	89648.7	14869.9	26.96%	4.47%	**6.06%**	3.8
2052	91556.2	14883.8	27.53%	**4.48%**	**6.06%**	3.8
2053	93463.6	14895.8	28.11%	**4.48%**	**6.06%**	3.8
2054	95371.0	14905.8	28.68%	**4.48%**	**6.06%**	3.8
2055	97278.4	14914.1	29.25%	**4.48%**	**6.06%**	3.8
2056	97278.4	13256.7	29.25%	3.99%	5.00%	3.1
2057	97278.4	11810.1	29.25%	3.55%	4.13%	2.6
2058	97278.4	10546.1	29.25%	3.17%	3.43%	2.1
2059	97278.4	9439.9	29.25%	2.84%	2.85%	1.8
2060	97278.4	8469.3	29.25%	2.55%	2.38%	1.5
2061	97278.4	7614.9	29.25%	2.29%	2.00%	1.2
2062	97278.4	6859.6	29.25%	2.06%	1.69%	1.0
2063	97278.4	6189.0	29.25%	1.86%	1.43%	0.9
2064	97278.4	5590.5	29.25%	1.68%	1.22%	0.8
2065	97278.4	5053.5	29.25%	1.52%	1.04%	0.6
2066	97278.4	4569.6	29.25%	1.37%	0.90%	0.6
2067	97278.4	4129.4	29.25%	1.24%	0.78%	0.5
2068	97278.4	3728.3	29.25%	1.12%	0.67%	0.4
2069	97278.4	3361.5	29.25%	1.01%	0.58%	0.4
2070	97278.4	3032.0	29.25%	0.91%	0.50%	0.3
2071	97278.4	2736.8	29.25%	0.82%	0.43%	0.3
2072	97278.4	2471.6	29.25%	0.74%	0.37%	0.2
2073	97278.4	2233.1	29.25%	0.67%	0.32%	0.2
2074	97278.4	2018.7	29.25%	0.61%	0.27%	0.2
2075	97278.4	1826.3	29.25%	0.55%	0.23%	0.1
2076	97278.4	1654.0	29.25%	0.50%	0.19%	0.1
2077	97278.4	1499.6	29.25%	0.45%	0.16%	0.1
2078	97278.4	1360.4	29.25%	0.41%	0.13%	0.1
2079	97278.4	1234.6	29.25%	0.37%	0.11%	0.1
2080	97278.4	1120.6	29.25%	0.34%	0.09%	0.1
2081	97278.4	1017.1	29.25%	0.31%	0.07%	0.0
2082	97278.4	922.8	29.25%	0.28%	0.06%	0.0
2083	97278.4	836.8	29.25%	0.25%	0.05%	0.0
2084	97278.4	757.4	29.25%	0.23%	0.04%	0.0
2085	97278.4	684.0	29.25%	0.21%	0.03%	0.0
2086	97278.4	616.4	29.25%	0.19%	0.03%	0.0
2087	97278.4	554.3	29.25%	0.17%	0.02%	0.0
2088	97278.4	497.5	29.25%	0.15%	0.02%	0.0
2089	97278.4	445.6	29.25%	0.13%	0.02%	0.0
2090	97278.4	398.3	29.25%	0.12%	0.01%	0.0
2091	97278.4	355.3	29.25%	0.11%	0.01%	0.0
2092	97278.4	316.3	29.25%	0.10%	0.01%	0.0
2093	97278.4	281.1	29.25%	0.08%	0.01%	0.0
2094	97278.4	249.3	29.25%	0.07%	0.01%	0.0
2095	97278.4	220.6	29.25%	0.07%	0.01%	0.0
2096	97278.4	194.8	29.25%	0.06%	0.01%	0.0
2097	97278.4	167.4	29.25%	0.05%	0.00%	0.0
2098	97278.4	142.4	29.25%	0.04%	0.00%	0.0
2099	97278.4	119.7	29.25%	0.04%	0.00%	0.0
2100	97278.4	99.4	29.25%	0.03%	0.00%	0.0
2101	97278.4	81.3	29.25%	0.02%	0.00%	0.0
2102	97278.4	65.3	29.25%	0.02%	0.00%	0.0
2103	97278.4	51.4	29.25%	0.02%	0.00%	0.0
2104	97278.4	39.5	29.25%	0.01%	0.00%	0.0


S22
% Increase
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

S22						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	3314.5	2856.3	0.41%	0.36%	0.73%	0.5
2006	6629.0	5318.2	0.82%	0.66%	1.31%	0.8
2007	9943.5	7442.3	1.24%	0.93%	1.79%	1.1
2008	13258.0	9279.1	1.65%	1.15%	2.17%	1.4
2009	16572.5	10872.9	2.06%	1.35%	2.47%	1.6
2010	19887.0	12262.3	2.47%	1.53%	2.72%	1.7
2011	23201.6	13480.7	2.89%	1.68%	2.92%	1.8
2012	26516.1	14556.6	3.30%	1.81%	3.09%	1.9
2013	29830.6	15513.9	3.71%	1.93%	3.22%	2.0
2014	33145.1	16372.5	4.12%	2.04%	3.33%	2.1
2015	36459.6	17148.3	4.54%	2.13%	3.42%	2.2
2016	39774.1	17854.3	4.95%	2.22%	3.50%	2.2
2017	43088.6	18500.1	5.36%	2.30%	3.57%	2.2
2018	46403.1	19092.9	5.77%	2.38%	3.62%	2.3
2019	49717.6	19626.5	6.19%	2.44%	3.67%	2.3
2020	53032.1	20103.3	6.60%	2.50%	3.71%	2.3
2021	56346.6	20529.5	7.01%	2.55%	3.75%	2.4
2022	59661.1	20910.3	7.42%	2.60%	3.78%	2.4
2023	62975.7	21250.0	7.84%	2.64%	3.81%	2.4
2024	66290.2	21552.4	8.25%	2.68%	3.83%	2.4
2025	69604.7	21821.2	8.66%	2.72%	3.85%	2.4
2026	72919.2	22059.8	9.07%	2.75%	3.87%	2.4
2027	76233.7	22272.8	9.49%	2.77%	3.89%	2.5
2028	79548.2	22463.5	9.90%	2.80%	3.90%	2.5
2029	82862.7	22634.8	10.31%	2.82%	3.92%	2.5
2030	86177.2	22789.0	10.72%	2.84%	3.92%	2.5
2031	89491.7	22928.4	11.14%	2.85%	3.93%	2.5
2032	92806.2	23055.0	11.55%	2.87%	3.94%	2.5
2033	96120.7	23171.9	11.96%	2.88%	3.94%	2.5
2034	99435.2	23279.9	12.37%	2.90%	3.95%	2.5
2035	102749.7	23379.3	12.79%	2.91%	3.95%	2.5
2036	106064.3	23470.6	13.20%	2.92%	3.95%	2.5
2037	109378.8	23554.2	13.61%	2.93%	3.95%	2.5
2038	112693.3	23630.6	14.02%	2.94%	3.96%	2.5
2039	116007.8	23700.2	14.44%	2.95%	3.96%	2.5
2040	119322.3	23763.4	14.85%	2.96%	3.96%	2.5
2041	122636.8	23820.7	15.26%	2.96%	3.96%	2.5
2042	125951.3	23872.5	15.67%	2.97%	3.96%	2.5
2043	129265.8	23919.3	16.09%	2.98%	3.96%	2.5
2044	132580.3	23961.5	16.50%	2.98%	3.96%	2.5
2045	135894.8	23999.5	16.91%	2.99%	3.96%	2.5
2046	139209.3	24039.9	17.32%	2.99%	3.96%	2.5
2047	142523.8	24076.6	17.74%	3.00%	3.96%	2.5
2048	145838.4	24109.9	18.15%	3.00%	3.96%	2.5
2049	149152.9	24139.8	18.56%	3.00%	3.96%	2.5
2050	152467.4	24166.5	18.97%	3.01%	3.96%	2.5
2051	155781.9	24190.0	19.39%	3.01%	3.96%	2.5
2052	159096.4	24210.4	19.80%	3.01%	3.96%	2.5
2053	162410.9	24228.0	20.21%	**3.02%**	**3.97%**	2.5
2054	165725.4	24242.8	20.62%	**3.02%**	**3.97%**	2.5
2055	169039.9	24254.9	21.04%	**3.02%**	**3.97%**	2.5
2056	169039.9	21408.3	21.04%	2.66%	3.24%	2.0
2057	169039.9	18953.9	21.04%	2.36%	2.65%	1.7
2058	169039.9	16835.2	21.04%	2.10%	2.18%	1.4
2059	169039.9	15002.0	21.04%	1.87%	1.80%	1.1
2060	169039.9	13410.3	21.04%	1.67%	1.49%	0.9
2061	169039.9	12021.7	21.04%	1.50%	1.24%	0.8
2062	169039.9	10803.4	21.04%	1.34%	1.04%	0.7
2063	169039.9	9727.5	21.04%	1.21%	0.88%	0.6
2064	169039.9	8770.2	21.04%	1.09%	0.74%	0.5
2065	169039.9	7912.0	21.04%	0.98%	0.63%	0.4
2066	169039.9	7137.7	21.04%	0.89%	0.54%	0.3
2067	169039.9	6431.8	21.04%	0.80%	0.46%	0.3
2068	169039.9	5786.0	21.04%	0.72%	0.40%	0.3
2069	169039.9	5193.2	21.04%	0.65%	0.35%	0.2
2070	169039.9	4659.5	21.04%	0.58%	0.30%	0.2
2071	169039.9	4182.8	21.04%	0.52%	0.26%	0.2
2072	169039.9	3756.6	21.04%	0.47%	0.22%	0.1
2073	169039.9	3375.8	21.04%	0.42%	0.19%	0.1
2074	169039.9	3036.1	21.04%	0.38%	0.16%	0.1
2075	169039.9	2733.6	21.04%	0.34%	0.13%	0.1
2076	169039.9	2464.9	21.04%	0.31%	0.11%	0.1
2077	169039.9	2226.3	21.04%	0.28%	0.09%	0.1
2078	169039.9	2013.3	21.04%	0.25%	0.08%	0.0
2079	169039.9	1822.5	21.04%	0.23%	0.06%	0.0
2080	169039.9	1651.3	21.04%	0.21%	0.05%	0.0
2081	169039.9	1497.1	21.04%	0.19%	0.04%	0.0
2082	169039.9	1357.6	21.04%	0.17%	0.03%	0.0
2083	169039.9	1231.0	21.04%	0.15%	0.03%	0.0
2084	169039.9	1114.1	21.04%	0.14%	0.02%	0.0
2085	169039.9	1006.2	21.04%	0.13%	0.02%	0.0
2086	169039.9	906.8	21.04%	0.11%	0.02%	0.0
2087	169039.9	815.5	21.04%	0.10%	0.01%	0.0
2088	169039.9	731.8	21.04%	0.09%	0.01%	0.0
2089	169039.9	655.5	21.04%	0.08%	0.01%	0.0
2090	169039.9	585.9	21.04%	0.07%	0.01%	0.0
2091	169039.9	522.7	21.04%	0.07%	0.01%	0.0
2092	169039.9	465.3	21.04%	0.06%	0.01%	0.0
2093	169039.9	413.5	21.04%	0.05%	0.01%	0.0
2094	169039.9	366.7	21.04%	0.05%	0.00%	0.0
2095	169039.9	324.5	21.04%	0.04%	0.00%	0.0
2096	169039.9	286.6	21.04%	0.04%	0.00%	0.0
2097	169039.9	246.2	21.04%	0.03%	0.00%	0.0
2098	169039.9	209.4	21.04%	0.03%	0.00%	0.0
2099	169039.9	176.1	21.04%	0.02%	0.00%	0.0
2100	169039.9	146.2	21.04%	0.02%	0.00%	0.0
2101	169039.9	119.6	21.04%	0.01%	0.00%	0.0
2102	169039.9	96.1	21.04%	0.01%	0.00%	0.0
2103	169039.9	75.6	21.04%	0.01%	0.00%	0.0
2104	169039.9	58.0	21.04%	0.01%	0.00%	0.0

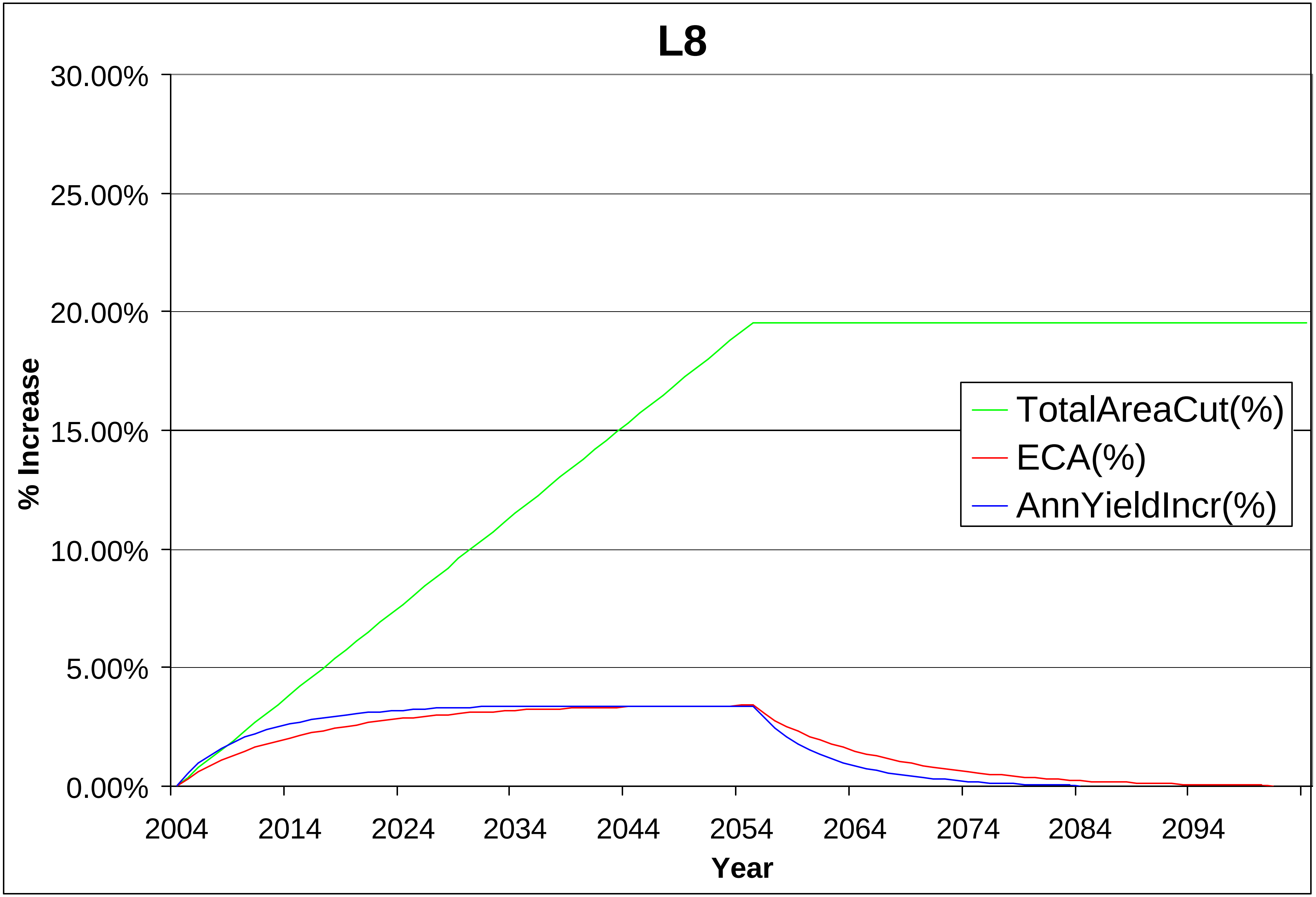

A15
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year

A15						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	4575.4	4077.1	0.32%	0.28%	0.35%	0.3
2006	9150.9	7711.5	0.64%	0.54%	0.65%	0.6
2007	13726.3	10954.2	0.96%	0.76%	0.89%	0.8
2008	18301.8	13851.1	1.27%	0.96%	1.10%	1.0
2009	22877.2	16443.7	1.59%	1.14%	1.27%	1.1
2010	27452.7	18769.2	1.91%	1.31%	1.41%	1.2
2011	32028.1	20860.7	2.23%	1.45%	1.54%	1.4
2012	36603.6	22747.6	2.55%	1.58%	1.64%	1.4
2013	41179.0	24455.6	2.87%	1.70%	1.72%	1.5
2014	45754.5	26007.1	3.19%	1.81%	1.80%	1.6
2015	50329.9	27421.4	3.50%	1.91%	1.86%	1.6
2016	54905.4	28715.0	3.82%	2.00%	1.92%	1.7
2017	59480.8	29901.7	4.14%	2.08%	1.96%	1.7
2018	64056.3	30992.9	4.46%	2.16%	2.01%	1.8
2019	68631.7	31983.3	4.78%	2.23%	2.04%	1.8
2020	73207.2	32884.4	5.10%	2.29%	2.08%	1.8
2021	77782.6	33707.3	5.41%	2.35%	2.11%	1.9
2022	82358.1	34460.2	5.73%	2.40%	2.13%	1.9
2023	86933.5	35149.2	6.05%	2.45%	2.16%	1.9
2024	91509.0	35779.0	6.37%	2.49%	2.18%	1.9
2025	96084.4	36353.9	6.69%	2.53%	2.19%	1.9
2026	100659.9	36878.7	7.01%	2.57%	2.21%	1.9
2027	105235.3	37360.1	7.33%	2.60%	2.22%	2.0
2028	109810.8	37802.5	7.64%	2.63%	2.24%	2.0
2029	114386.2	38209.1	7.96%	2.66%	2.25%	2.0
2030	118961.6	38582.9	8.28%	2.69%	2.25%	2.0
2031	123537.1	38926.8	8.60%	2.71%	2.26%	2.0
2032	128112.5	39243.1	8.92%	2.73%	2.27%	2.0
2033	132688.0	39535.7	9.24%	2.75%	2.27%	2.0
2034	137263.4	39805.9	9.56%	2.77%	2.27%	2.0
2035	141838.9	40054.7	9.87%	2.79%	2.27%	2.0
2036	146414.3	40283.2	10.19%	2.80%	2.28%	2.0
2037	150989.8	40492.5	10.51%	2.82%	2.28%	2.0
2038	155565.2	40683.7	10.83%	2.83%	2.28%	2.0
2039	160140.7	40857.8	11.15%	2.84%	2.28%	2.0
2040	164716.1	41016.1	11.47%	2.86%	2.28%	2.0
2041	169291.6	41159.5	11.79%	2.87%	2.28%	2.0
2042	173867.0	41289.3	12.10%	2.87%	2.28%	2.0
2043	178442.5	41406.4	12.42%	2.88%	2.28%	2.0
2044	183017.9	41512.0	12.74%	2.89%	2.28%	2.0
2045	187593.4	41607.0	13.06%	2.90%	2.28%	2.0
2046	192168.8	41708.1	13.38%	2.90%	**2.29%**	2.0
2047	196744.3	41800.1	13.70%	2.91%	**2.29%**	2.0
2048	201319.7	41883.4	14.01%	2.92%	**2.29%**	2.0
2049	205895.2	41958.3	14.33%	2.92%	**2.29%**	2.0
2050	210470.6	42025.0	14.65%	2.93%	**2.29%**	2.0
2051	215046.1	42083.8	14.97%	2.93%	**2.29%**	2.0
2052	219621.5	42135.0	15.29%	2.93%	**2.29%**	2.0
2053	224197.0	42179.0	15.61%	**2.94%**	**2.29%**	2.0
2054	228772.4	42216.0	15.93%	**2.94%**	**2.29%**	2.0
2055	233347.8	42246.4	16.24%	**2.94%**	**2.29%**	2.0
2056	233347.8	38193.6	16.24%	2.66%	1.94%	1.7
2057	233347.8	34577.7	16.24%	2.41%	1.64%	1.4
2058	233347.8	31348.6	16.24%	2.18%	1.40%	1.2
2059	233347.8	28460.6	16.24%	1.98%	1.19%	1.0
2060	233347.8	25873.3	16.24%	1.80%	1.02%	0.9
2061	233347.8	23550.0	16.24%	1.64%	0.87%	0.8
2062	233347.8	21458.7	16.24%	1.49%	0.75%	0.7
2063	233347.8	19571.8	16.24%	1.36%	0.65%	0.6
2064	233347.8	17863.9	16.24%	1.24%	0.56%	0.5
2065	233347.8	16313.3	16.24%	1.14%	0.49%	0.4
2066	233347.8	14902.9	16.24%	1.04%	0.43%	0.4
2067	233347.8	13609.3	16.24%	0.95%	0.37%	0.3
2068	233347.8	12422.6	16.24%	0.86%	0.32%	0.3
2069	233347.8	11331.3	16.24%	0.79%	0.28%	0.2
2070	233347.8	10341.0	16.24%	0.72%	0.25%	0.2
2071	233347.8	9439.9	16.24%	0.66%	0.21%	0.2
2072	233347.8	8617.0	16.24%	0.60%	0.18%	0.2
2073	233347.8	7864.1	16.24%	0.55%	0.16%	0.1
2074	233347.8	7175.1	16.24%	0.50%	0.13%	0.1
2075	233347.8	6545.3	16.24%	0.46%	0.11%	0.1
2076	233347.8	5970.3	16.24%	0.42%	0.09%	0.1
2077	233347.8	5445.6	16.24%	0.38%	0.08%	0.1
2078	233347.8	4964.2	16.24%	0.35%	0.06%	0.1
2079	233347.8	4521.8	16.24%	0.31%	0.05%	0.0
2080	233347.8	4115.2	16.24%	0.29%	0.04%	0.0
2081	233347.8	3741.3	16.24%	0.26%	0.03%	0.0
2082	233347.8	3397.5	16.24%	0.24%	0.03%	0.0
2083	233347.8	3081.2	16.24%	0.21%	0.02%	0.0
2084	233347.8	2788.6	16.24%	0.19%	0.02%	0.0
2085	233347.8	2518.4	16.24%	0.18%	0.02%	0.0
2086	233347.8	2269.6	16.24%	0.16%	0.01%	0.0
2087	233347.8	2041.1	16.24%	0.14%	0.01%	0.0
2088	233347.8	1831.8	16.24%	0.13%	0.01%	0.0
2089	233347.8	1640.6	16.24%	0.11%	0.01%	0.0
2090	233347.8	1466.4	16.24%	0.10%	0.01%	0.0
2091	233347.8	1308.2	16.24%	0.09%	0.01%	0.0
2092	233347.8	1164.7	16.24%	0.08%	0.01%	0.0
2093	233347.8	1035.0	16.24%	0.07%	0.00%	0.0
2094	233347.8	917.9	16.24%	0.06%	0.00%	0.0
2095	233347.8	812.3	16.24%	0.06%	0.00%	0.0
2096	233347.8	717.3	16.24%	0.05%	0.00%	0.0
2097	233347.8	616.2	16.24%	0.04%	0.00%	0.0
2098	233347.8	524.2	16.24%	0.04%	0.00%	0.0
2099	233347.8	440.9	16.24%	0.03%	0.00%	0.0
2100	233347.8	366.0	16.24%	0.03%	0.00%	0.0
2101	233347.8	299.3	16.24%	0.02%	0.00%	0.0
2102	233347.8	240.5	16.24%	0.02%	0.00%	0.0
2103	233347.8	189.2	16.24%	0.01%	0.00%	0.0
2104	233347.8	145.3	16.24%	0.01%	0.00%	0.0

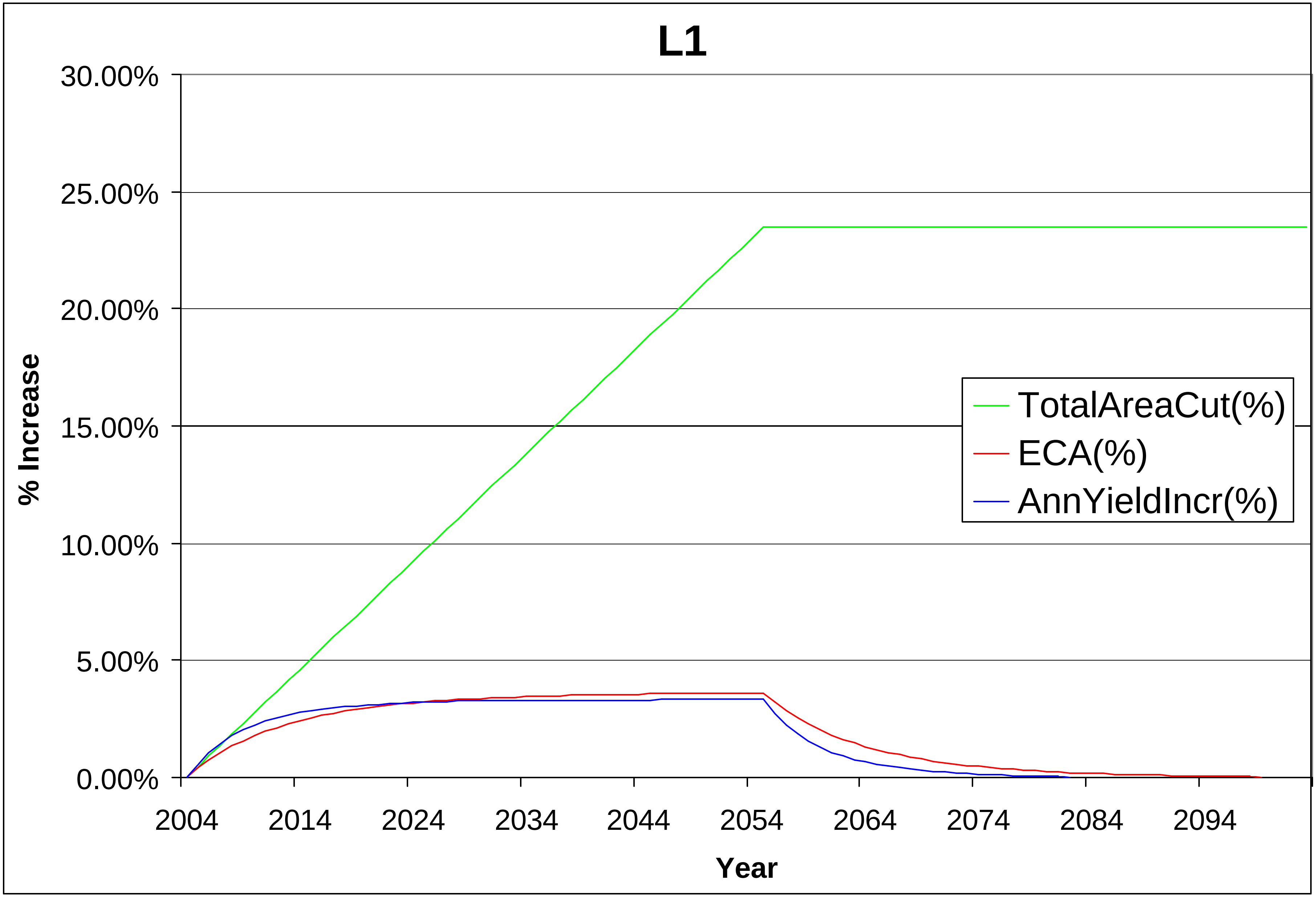


L2
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

L2						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	1381.4	1208.1	0.46%	0.40%	0.63%	0.5
2006	2762.8	2267.6	0.92%	0.75%	1.15%	0.9
2007	4144.2	3200.2	1.38%	1.06%	1.58%	1.3
2008	5525.6	4025.2	1.84%	1.34%	1.94%	1.6
2009	6907.0	4759.5	2.30%	1.58%	2.24%	1.8
2010	8288.4	5417.5	2.76%	1.80%	2.50%	2.0
2011	9669.7	6011.6	3.22%	2.00%	2.72%	2.2
2012	11051.1	6552.3	3.68%	2.18%	2.91%	2.3
2013	12432.5	7048.2	4.14%	2.35%	3.07%	2.5
2014	13813.9	7506.2	4.60%	2.50%	3.21%	2.6
2015	15195.3	7932.0	5.06%	2.64%	3.34%	2.7
2016	16576.7	8329.8	5.52%	2.77%	3.45%	2.8
2017	17958.1	8702.6	5.98%	2.90%	3.54%	2.8
2018	19339.5	9052.6	6.43%	3.01%	3.63%	2.9
2019	20720.9	9377.4	6.89%	3.12%	3.70%	3.0
2020	22102.3	9676.4	7.35%	3.22%	3.77%	3.0
2021	23483.7	9951.7	7.81%	3.31%	3.83%	3.1
2022	24865.1	10204.9	8.27%	3.40%	3.89%	3.1
2023	26246.4	10437.4	8.73%	3.47%	3.93%	3.1
2024	27627.8	10650.6	9.19%	3.54%	3.98%	3.2
2025	29009.2	10846.0	9.65%	3.61%	4.01%	3.2
2026	30390.6	11024.8	10.11%	3.67%	4.04%	3.2
2027	31772.0	11188.8	10.57%	3.72%	4.07%	3.3
2028	33153.4	11339.1	11.03%	3.77%	4.10%	3.3
2029	34534.8	11477.1	11.49%	3.82%	4.11%	3.3
2030	35916.2	11603.7	11.95%	3.86%	4.13%	3.3
2031	37297.6	11720.0	12.41%	3.90%	4.14%	3.3
2032	38679.0	11826.9	12.87%	3.94%	4.16%	3.3
2033	40060.4	11925.8	13.33%	3.97%	4.16%	3.3
2034	41441.8	12017.1	13.79%	4.00%	4.17%	3.3
2035	42823.2	12101.1	14.25%	4.03%	4.17%	3.3
2036	44204.5	12178.4	14.71%	4.05%	4.18%	3.3
2037	45585.9	12249.1	15.17%	4.08%	4.18%	3.3
2038	46967.3	12313.7	15.63%	4.10%	4.18%	3.3
2039	48348.7	12372.5	16.09%	4.12%	4.19%	3.3
2040	49730.1	12426.0	16.55%	4.13%	4.19%	3.4
2041	51111.5	12474.4	17.01%	4.15%	4.19%	3.4
2042	52492.9	12518.3	17.47%	4.17%	4.19%	3.4
2043	53874.3	12557.9	17.93%	4.18%	4.19%	3.4
2044	55255.7	12593.5	18.39%	4.19%	4.19%	3.4
2045	56637.1	12625.6	18.85%	4.20%	**4.20%**	3.4
2046	58018.5	12659.8	19.30%	4.21%	**4.20%**	3.4
2047	59399.9	12690.9	19.76%	4.22%	**4.20%**	3.4
2048	60781.2	12719.0	20.22%	4.23%	**4.20%**	3.4
2049	62162.6	12744.3	20.68%	4.24%	**4.20%**	3.4
2050	63544.0	12766.9	21.14%	4.25%	**4.20%**	3.4
2051	64925.4	12786.7	21.60%	4.25%	**4.20%**	3.4
2052	66306.8	12804.1	22.06%	4.26%	**4.20%**	3.4
2053	67688.2	12818.9	22.52%	**4.27%**	**4.20%**	3.4
2054	69069.6	12831.4	22.98%	**4.27%**	**4.20%**	3.4
2055	70451.0	12841.7	23.44%	**4.27%**	**4.20%**	3.4
2056	70451.0	11641.8	23.44%	3.87%	3.57%	2.9
2057	70451.0	10588.6	23.44%	3.52%	3.05%	2.4
2058	70451.0	9660.5	23.44%	3.21%	2.62%	2.1
2059	70451.0	8838.5	23.44%	2.94%	2.26%	1.8
2060	70451.0	8106.0	23.44%	2.70%	1.96%	1.6
2061	70451.0	7448.8	23.44%	2.48%	1.70%	1.4
2062	70451.0	6854.7	23.44%	2.28%	1.48%	1.2
2063	70451.0	6314.1	23.44%	2.10%	1.29%	1.0
2064	70451.0	5818.2	23.44%	1.94%	1.13%	0.9
2065	70451.0	5360.5	23.44%	1.78%	0.99%	0.8
2066	70451.0	4936.0	23.44%	1.64%	0.86%	0.7
2067	70451.0	4538.2	23.44%	1.51%	0.75%	0.6
2068	70451.0	4165.4	23.44%	1.39%	0.66%	0.5
2069	70451.0	3815.4	23.44%	1.27%	0.57%	0.5
2070	70451.0	3490.7	23.44%	1.16%	0.50%	0.4
2071	70451.0	3191.6	23.44%	1.06%	0.43%	0.3
2072	70451.0	2916.3	23.44%	0.97%	0.37%	0.3
2073	70451.0	2663.1	23.44%	0.89%	0.32%	0.3
2074	70451.0	2430.6	23.44%	0.81%	0.27%	0.2
2075	70451.0	2217.4	23.44%	0.74%	0.23%	0.2
2076	70451.0	2022.0	23.44%	0.67%	0.19%	0.2
2077	70451.0	1843.2	23.44%	0.61%	0.16%	0.1
2078	70451.0	1679.2	23.44%	0.56%	0.13%	0.1
2079	70451.0	1528.9	23.44%	0.51%	0.11%	0.1
2080	70451.0	1390.9	23.44%	0.46%	0.09%	0.1
2081	70451.0	1264.3	23.44%	0.42%	0.07%	0.1
2082	70451.0	1148.0	23.44%	0.38%	0.06%	0.0
2083	70451.0	1041.1	23.44%	0.35%	0.05%	0.0
2084	70451.0	942.2	23.44%	0.31%	0.04%	0.0
2085	70451.0	850.9	23.44%	0.28%	0.03%	0.0
2086	70451.0	766.9	23.44%	0.26%	0.03%	0.0
2087	70451.0	689.7	23.44%	0.23%	0.02%	0.0
2088	70451.0	618.9	23.44%	0.21%	0.02%	0.0
2089	70451.0	554.3	23.44%	0.18%	0.02%	0.0
2090	70451.0	495.5	23.44%	0.16%	0.01%	0.0
2091	70451.0	442.0	23.44%	0.15%	0.01%	0.0
2092	70451.0	393.6	23.44%	0.13%	0.01%	0.0
2093	70451.0	349.7	23.44%	0.12%	0.01%	0.0
2094	70451.0	310.1	23.44%	0.10%	0.01%	0.0
2095	70451.0	274.5	23.44%	0.09%	0.01%	0.0
2096	70451.0	242.4	23.44%	0.08%	0.01%	0.0
2097	70451.0	208.2	23.44%	0.07%	0.00%	0.0
2098	70451.0	177.1	23.44%	0.06%	0.00%	0.0
2099	70451.0	149.0	23.44%	0.05%	0.00%	0.0
2100	70451.0	123.7	23.44%	0.04%	0.00%	0.0
2101	70451.0	101.1	23.44%	0.03%	0.00%	0.0
2102	70451.0	81.3	23.44%	0.03%	0.00%	0.0
2103	70451.0	63.9	23.44%	0.02%	0.00%	0.0
2104	70451.0	49.1	23.44%	0.02%	0.00%	0.0

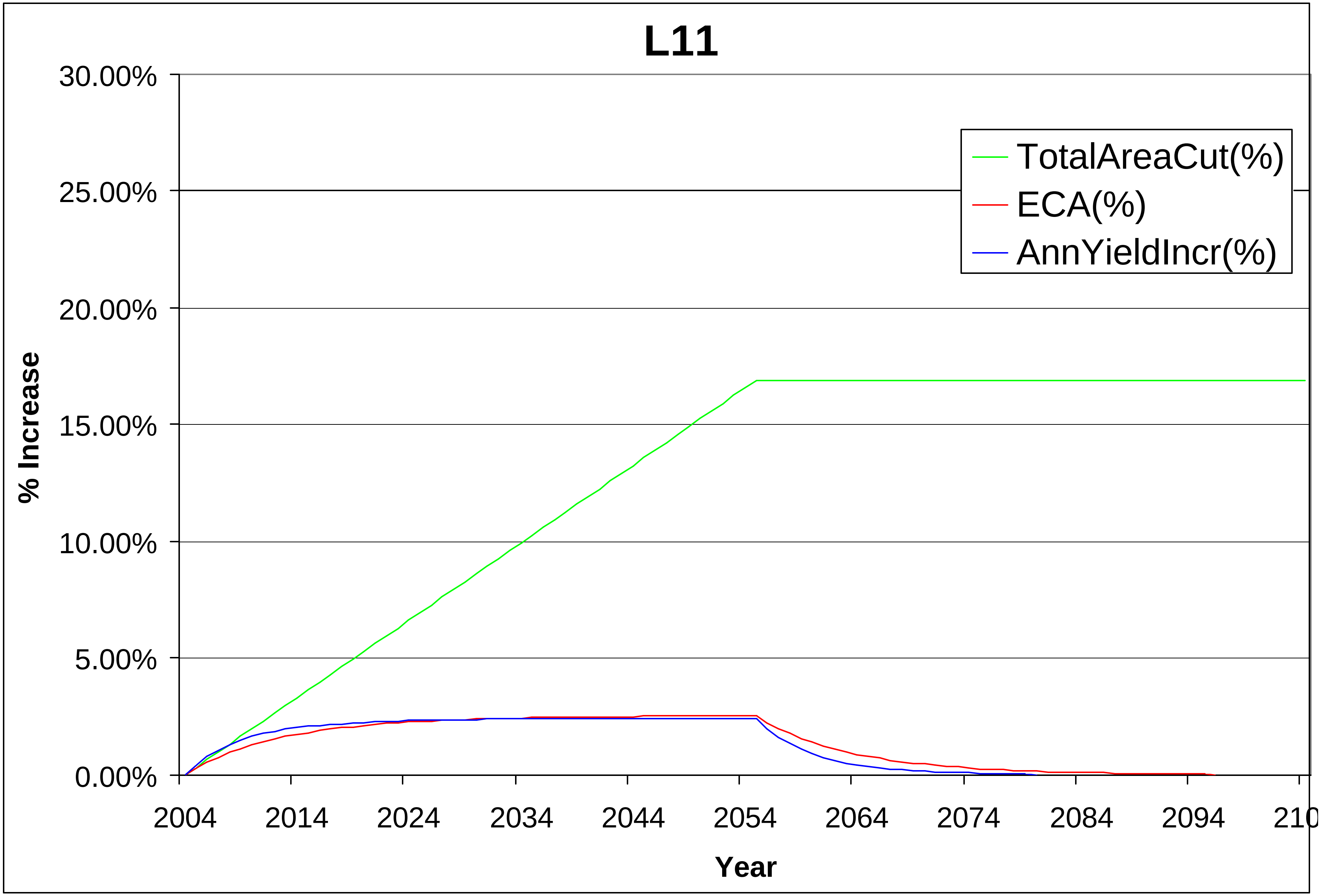

L8
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

L8						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	483.4	420.7	0.38%	0.33%	0.52%	0.4
2006	966.9	787.7	0.77%	0.62%	0.96%	0.8
2007	1450.3	1109.1	1.15%	0.88%	1.31%	1.0
2008	1933.8	1391.7	1.53%	1.10%	1.61%	1.3
2009	2417.2	1641.8	1.92%	1.30%	1.85%	1.5
2010	2900.7	1864.7	2.30%	1.48%	2.06%	1.6
2011	3384.1	2064.9	2.68%	1.64%	2.23%	1.8
2012	3867.6	2246.2	3.07%	1.78%	2.38%	1.9
2013	4351.0	2411.8	3.45%	1.91%	2.51%	2.0
2014	4834.5	2564.2	3.83%	2.03%	2.62%	2.1
2015	5317.9	2705.4	4.22%	2.14%	2.72%	2.2
2016	5801.4	2837.0	4.60%	2.25%	2.81%	2.2
2017	6284.8	2960.1	4.98%	2.35%	2.88%	2.3
2018	6768.2	3075.5	5.37%	2.44%	2.94%	2.4
2019	7251.7	3182.2	5.75%	2.52%	3.00%	2.4
2020	7735.1	3280.2	6.13%	2.60%	3.05%	2.4
2021	8218.6	3370.0	6.52%	2.67%	3.10%	2.5
2022	8702.0	3452.3	6.90%	2.74%	3.14%	2.5
2023	9185.5	3527.6	7.28%	2.80%	3.18%	2.5
2024	9668.9	3596.4	7.67%	2.85%	3.21%	2.6
2025	10152.4	3659.2	8.05%	2.90%	3.24%	2.6
2026	10635.8	3716.5	8.43%	2.95%	3.26%	2.6
2027	11119.3	3768.8	8.82%	2.99%	3.28%	2.6
2028	11602.7	3816.6	9.20%	3.03%	3.30%	2.6
2029	12086.2	3860.3	9.58%	3.06%	3.31%	2.7
2030	12569.6	3900.3	9.97%	3.09%	3.33%	2.7
2031	13053.0	3937.1	10.35%	3.12%	3.34%	2.7
2032	13536.5	3970.7	10.73%	3.15%	3.35%	2.7
2033	14019.9	4001.9	11.11%	3.17%	3.35%	2.7
2034	14503.4	4030.7	11.50%	3.20%	3.36%	2.7
2035	14986.8	4057.2	11.88%	3.22%	3.36%	2.7
2036	15470.3	4081.5	12.26%	3.24%	3.36%	2.7
2037	15953.7	4103.8	12.65%	3.25%	3.36%	2.7
2038	16437.2	4124.1	13.03%	3.27%	3.37%	2.7
2039	16920.6	4142.7	13.41%	3.28%	3.37%	2.7
2040	17404.1	4159.5	13.80%	3.30%	3.37%	2.7
2041	17887.5	4174.8	14.18%	3.31%	3.37%	2.7
2042	18370.9	4188.6	14.56%	3.32%	3.37%	2.7
2043	18854.4	4201.1	14.95%	3.33%	3.37%	2.7
2044	19337.8	4212.3	15.33%	3.34%	3.37%	2.7
2045	19821.3	4222.4	15.71%	3.35%	**3.38%**	2.7
2046	20304.7	4233.2	16.10%	3.36%	**3.38%**	2.7
2047	20788.2	4243.0	16.48%	3.36%	**3.38%**	2.7
2048	21271.6	4251.8	16.86%	3.37%	**3.38%**	2.7
2049	21755.1	4259.8	17.25%	3.38%	**3.38%**	2.7
2050	22238.5	4266.9	17.63%	3.38%	**3.38%**	2.7
2051	22722.0	4273.2	18.01%	3.39%	**3.38%**	2.7
2052	23205.4	4278.6	18.40%	3.39%	**3.38%**	2.7
2053	23688.9	4283.3	18.78%	**3.40%**	**3.38%**	2.7
2054	24172.3	4287.3	19.16%	**3.40%**	**3.38%**	2.7
2055	24655.7	4290.5	19.55%	**3.40%**	**3.38%**	2.7
2056	24655.7	3872.4	19.55%	3.07%	2.86%	2.3
2057	24655.7	3507.3	19.55%	2.78%	2.42%	1.9
2058	24655.7	3187.4	19.55%	2.53%	2.07%	1.7
2059	24655.7	2905.8	19.55%	2.30%	1.77%	1.4
2060	24655.7	2656.2	19.55%	2.11%	1.53%	1.2
2061	24655.7	2433.6	19.55%	1.93%	1.32%	1.1
2062	24655.7	2233.4	19.55%	1.77%	1.15%	0.9
2063	24655.7	2052.1	19.55%	1.63%	1.00%	0.8
2064	24655.7	1886.5	19.55%	1.50%	0.87%	0.7
2065	24655.7	1734.2	19.55%	1.37%	0.76%	0.6
2066	24655.7	1593.4	19.55%	1.26%	0.66%	0.5
2067	24655.7	1461.8	19.55%	1.16%	0.57%	0.5
2068	24655.7	1338.7	19.55%	1.06%	0.50%	0.4
2069	24655.7	1223.3	19.55%	0.97%	0.44%	0.3
2070	24655.7	1116.5	19.55%	0.89%	0.38%	0.3
2071	24655.7	1018.6	19.55%	0.81%	0.33%	0.3
2072	24655.7	928.7	19.55%	0.74%	0.28%	0.2
2073	24655.7	846.4	19.55%	0.67%	0.24%	0.2
2074	24655.7	771.2	19.55%	0.61%	0.20%	0.2
2075	24655.7	702.4	19.55%	0.56%	0.17%	0.1
2076	24655.7	639.6	19.55%	0.51%	0.14%	0.1
2077	24655.7	582.3	19.55%	0.46%	0.12%	0.1
2078	24655.7	530.0	19.55%	0.42%	0.10%	0.1
2079	24655.7	482.2	19.55%	0.38%	0.08%	0.1
2080	24655.7	438.5	19.55%	0.35%	0.07%	0.1
2081	24655.7	398.4	19.55%	0.32%	0.05%	0.0
2082	24655.7	361.7	19.55%	0.29%	0.04%	0.0
2083	24655.7	328.0	19.55%	0.26%	0.03%	0.0
2084	24655.7	296.9	19.55%	0.24%	0.03%	0.0
2085	24655.7	268.1	19.55%	0.21%	0.02%	0.0
2086	24655.7	241.6	19.55%	0.19%	0.02%	0.0
2087	24655.7	217.3	19.55%	0.17%	0.02%	0.0
2088	24655.7	195.0	19.55%	0.15%	0.02%	0.0
2089	24655.7	174.7	19.55%	0.14%	0.01%	0.0
2090	24655.7	156.1	19.55%	0.12%	0.01%	0.0
2091	24655.7	139.3	19.55%	0.11%	0.01%	0.0
2092	24655.7	124.0	19.55%	0.10%	0.01%	0.0
2093	24655.7	110.2	19.55%	0.09%	0.01%	0.0
2094	24655.7	97.7	19.55%	0.08%	0.01%	0.0
2095	24655.7	86.5	19.55%	0.07%	0.01%	0.0
2096	24655.7	76.4	19.55%	0.06%	0.00%	0.0
2097	24655.7	65.6	19.55%	0.05%	0.00%	0.0
2098	24655.7	55.8	19.55%	0.04%	0.00%	0.0
2099	24655.7	46.9	19.55%	0.04%	0.00%	0.0
2100	24655.7	39.0	19.55%	0.03%	0.00%	0.0
2101	24655.7	31.9	19.55%	0.03%	0.00%	0.0
2102	24655.7	25.6	19.55%	0.02%	0.00%	0.0
2103	24655.7	20.1	19.55%	0.02%	0.00%	0.0
2104	24655.7	15.5	19.55%	0.01%	0.00%	0.0



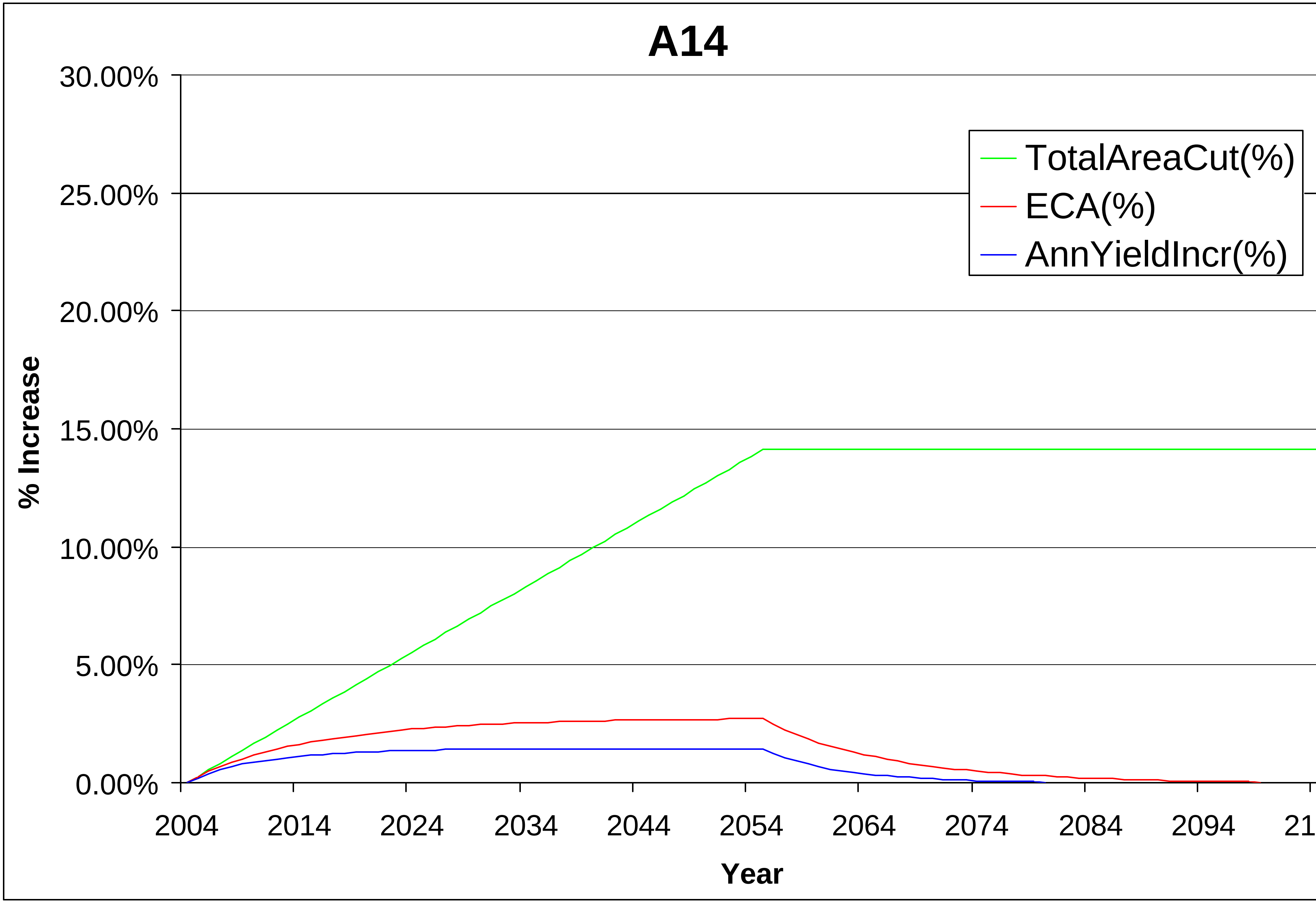
L1
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

L1						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	1536.3	1346.0	0.46%	0.40%	0.58%	0.5
2006	3072.5	2525.1	0.92%	0.76%	1.06%	0.9
2007	4608.8	3558.1	1.38%	1.07%	1.45%	1.2
2008	6145.1	4464.1	1.84%	1.34%	1.77%	1.5
2009	7681.3	5259.9	2.30%	1.58%	2.03%	1.7
2010	9217.6	5960.6	2.76%	1.79%	2.24%	1.9
2011	10753.8	6579.4	3.22%	1.97%	2.41%	2.0
2012	12290.1	7127.9	3.68%	2.14%	2.55%	2.1
2013	13826.4	7616.2	4.14%	2.28%	2.67%	2.2
2014	15362.6	8052.9	4.61%	2.41%	2.76%	2.3
2015	16898.9	8445.3	5.07%	2.53%	2.84%	2.4
2016	18435.2	8799.4	5.53%	2.64%	2.91%	2.4
2017	19971.4	9120.4	5.99%	2.73%	2.96%	2.5
2018	21507.7	9412.3	6.45%	2.82%	3.01%	2.5
2019	23044.0	9672.7	6.91%	2.90%	3.05%	2.6
2020	24580.2	9905.3	7.37%	2.97%	3.09%	2.6
2021	26116.5	10113.6	7.83%	3.03%	3.12%	2.6
2022	27652.8	10300.7	8.29%	3.09%	3.15%	2.6
2023	29189.0	10468.6	8.75%	3.14%	3.18%	2.7
2024	30725.3	10619.1	9.21%	3.18%	3.20%	2.7
2025	32261.5	10753.7	9.67%	3.22%	3.22%	2.7
2026	33797.8	10874.2	10.13%	3.26%	3.24%	2.7
2027	35334.1	10982.7	10.59%	3.29%	3.25%	2.7
2028	36870.3	11081.0	11.05%	3.32%	3.26%	2.7
2029	38406.6	11170.0	11.51%	3.35%	3.27%	2.7
2030	39942.9	11250.9	11.97%	3.37%	3.28%	2.8
2031	41479.1	11324.5	12.43%	3.39%	3.29%	2.8
2032	43015.4	11391.7	12.89%	3.41%	3.29%	2.8
2033	44551.7	11453.9	13.35%	3.43%	3.30%	2.8
2034	46087.9	11511.2	13.82%	3.45%	3.30%	2.8
2035	47624.2	11564.1	14.28%	3.47%	3.30%	2.8
2036	49160.4	11612.6	14.74%	3.48%	3.31%	2.8
2037	50696.7	11657.0	15.20%	3.49%	3.31%	2.8
2038	52233.0	11697.6	15.66%	3.51%	3.31%	2.8
2039	53769.2	11734.6	16.12%	3.52%	3.31%	2.8
2040	55305.5	11768.2	16.58%	3.53%	3.31%	2.8
2041	56841.8	11798.6	17.04%	3.54%	3.31%	2.8
2042	58378.0	11826.2	17.50%	3.55%	3.31%	2.8
2043	59914.3	11851.0	17.96%	3.55%	3.31%	2.8
2044	61450.6	11873.4	18.42%	3.56%	**3.32%**	2.8
2045	62986.8	11893.6	18.88%	3.57%	**3.32%**	2.8
2046	64523.1	11915.1	19.34%	3.57%	**3.32%**	2.8
2047	66059.4	11934.6	19.80%	3.58%	**3.32%**	2.8
2048	67595.6	11952.3	20.26%	3.58%	**3.32%**	2.8
2049	69131.9	11968.2	20.72%	3.59%	**3.32%**	2.8
2050	70668.1	11982.4	21.18%	3.59%	**3.32%**	2.8
2051	72204.4	11994.9	21.64%	3.60%	**3.32%**	2.8
2052	73740.7	12005.7	22.10%	3.60%	**3.32%**	2.8
2053	75276.9	12015.1	22.56%	3.60%	**3.32%**	2.8
2054	76813.2	12022.9	23.03%	3.60%	**3.32%**	2.8
2055	78349.5	12029.4	23.49%	**3.61%**	**3.32%**	2.8
2056	78349.5	10688.5	23.49%	3.20%	2.74%	2.3
2057	78349.5	9513.4	23.49%	2.85%	2.26%	1.9
2058	78349.5	8483.2	23.49%	2.54%	1.87%	1.6
2059	78349.5	7579.2	23.49%	2.27%	1.55%	1.3
2060	78349.5	6784.5	23.49%	2.03%	1.29%	1.1
2061	78349.5	6084.3	23.49%	1.82%	1.08%	0.9
2062	78349.5	5465.5	23.49%	1.64%	0.91%	0.8
2063	78349.5	4917.0	23.49%	1.47%	0.77%	0.6
2064	78349.5	4428.7	23.49%	1.33%	0.65%	0.5
2065	78349.5	3992.2	23.49%	1.20%	0.56%	0.5
2066	78349.5	3600.6	23.49%	1.08%	0.48%	0.4
2067	78349.5	3246.5	23.49%	0.97%	0.41%	0.3
2068	78349.5	2925.5	23.49%	0.88%	0.36%	0.3
2069	78349.5	2633.6	23.49%	0.79%	0.31%	0.3
2070	78349.5	2373.2	23.49%	0.71%	0.27%	0.2
2071	78349.5	2140.7	23.49%	0.64%	0.23%	0.2
2072	78349.5	1932.3	23.49%	0.58%	0.20%	0.2
2073	78349.5	1745.2	23.49%	0.52%	0.17%	0.1
2074	78349.5	1577.3	23.49%	0.47%	0.14%	0.1
2075	78349.5	1426.8	23.49%	0.43%	0.12%	0.1
2076	78349.5	1292.2	23.49%	0.39%	0.10%	0.1
2077	78349.5	1171.7	23.49%	0.35%	0.08%	0.1
2078	78349.5	1063.2	23.49%	0.32%	0.07%	0.1
2079	78349.5	964.9	23.49%	0.29%	0.06%	0.0
2080	78349.5	875.9	23.49%	0.26%	0.05%	0.0
2081	78349.5	795.0	23.49%	0.24%	0.04%	0.0
2082	78349.5	721.4	23.49%	0.22%	0.03%	0.0
2083	78349.5	654.2	23.49%	0.20%	0.02%	0.0
2084	78349.5	592.1	23.49%	0.18%	0.02%	0.0
2085	78349.5	534.7	23.49%	0.16%	0.02%	0.0
2086	78349.5	481.9	23.49%	0.14%	0.01%	0.0
2087	78349.5	433.3	23.49%	0.13%	0.01%	0.0
2088	78349.5	388.9	23.49%	0.12%	0.01%	0.0
2089	78349.5	348.3	23.49%	0.10%	0.01%	0.0
2090	78349.5	311.3	23.49%	0.09%	0.01%	0.0
2091	78349.5	277.7	23.49%	0.08%	0.01%	0.0
2092	78349.5	247.3	23.49%	0.07%	0.01%	0.0
2093	78349.5	219.7	23.49%	0.07%	0.00%	0.0
2094	78349.5	194.9	23.49%	0.06%	0.00%	0.0
2095	78349.5	172.5	23.49%	0.05%	0.00%	0.0
2096	78349.5	152.3	23.49%	0.05%	0.00%	0.0
2097	78349.5	130.8	23.49%	0.04%	0.00%	0.0
2098	78349.5	111.3	23.49%	0.03%	0.00%	0.0
2099	78349.5	93.6	23.49%	0.03%	0.00%	0.0
2100	78349.5	77.7	23.49%	0.02%	0.00%	0.0
2101	78349.5	63.5	23.49%	0.02%	0.00%	0.0
2102	78349.5	51.1	23.49%	0.02%	0.00%	0.0
2103	78349.5	40.2	23.49%	0.01%	0.00%	0.0
2104	78349.5	30.8	23.49%	0.01%	0.00%	0.0

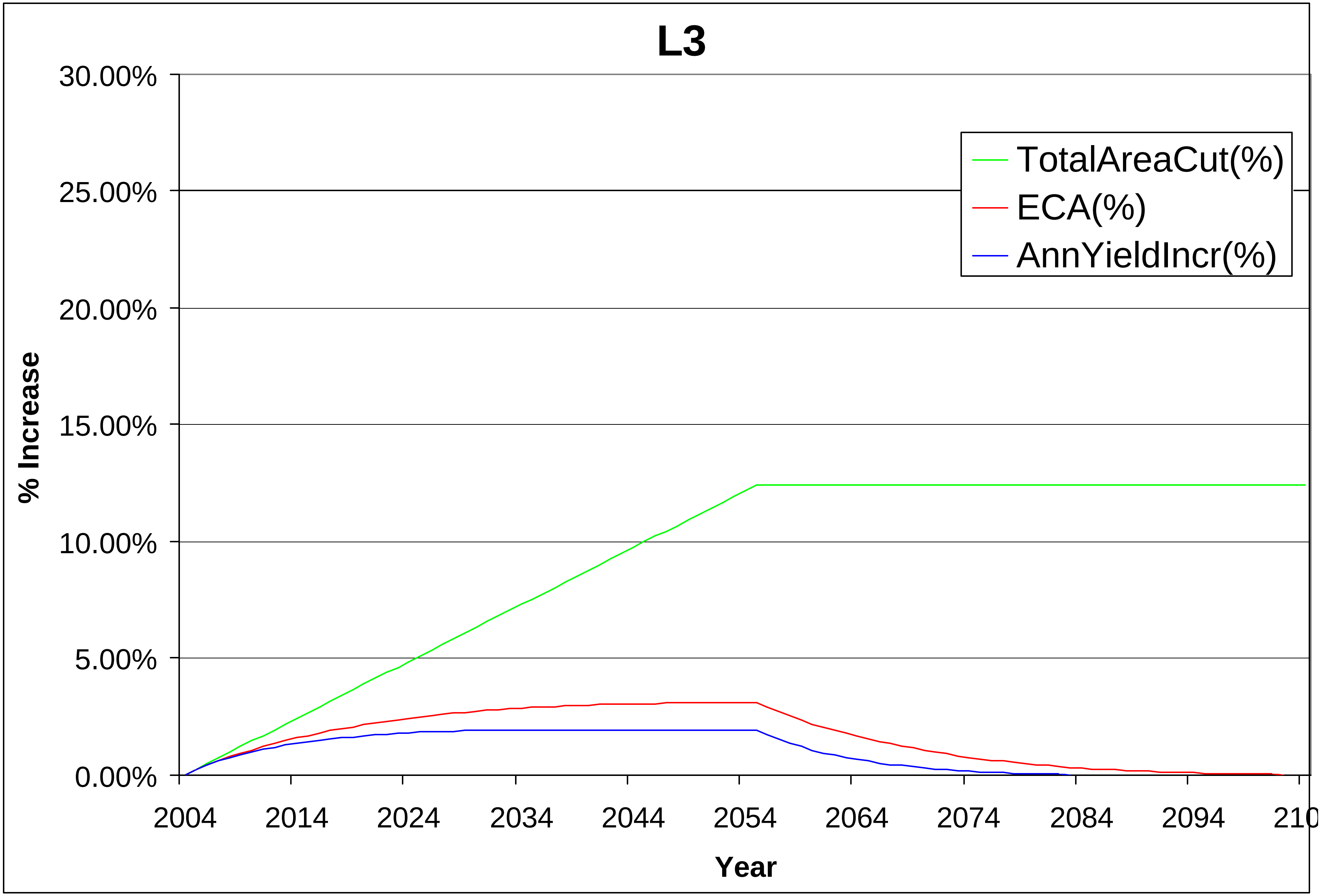


L11
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year

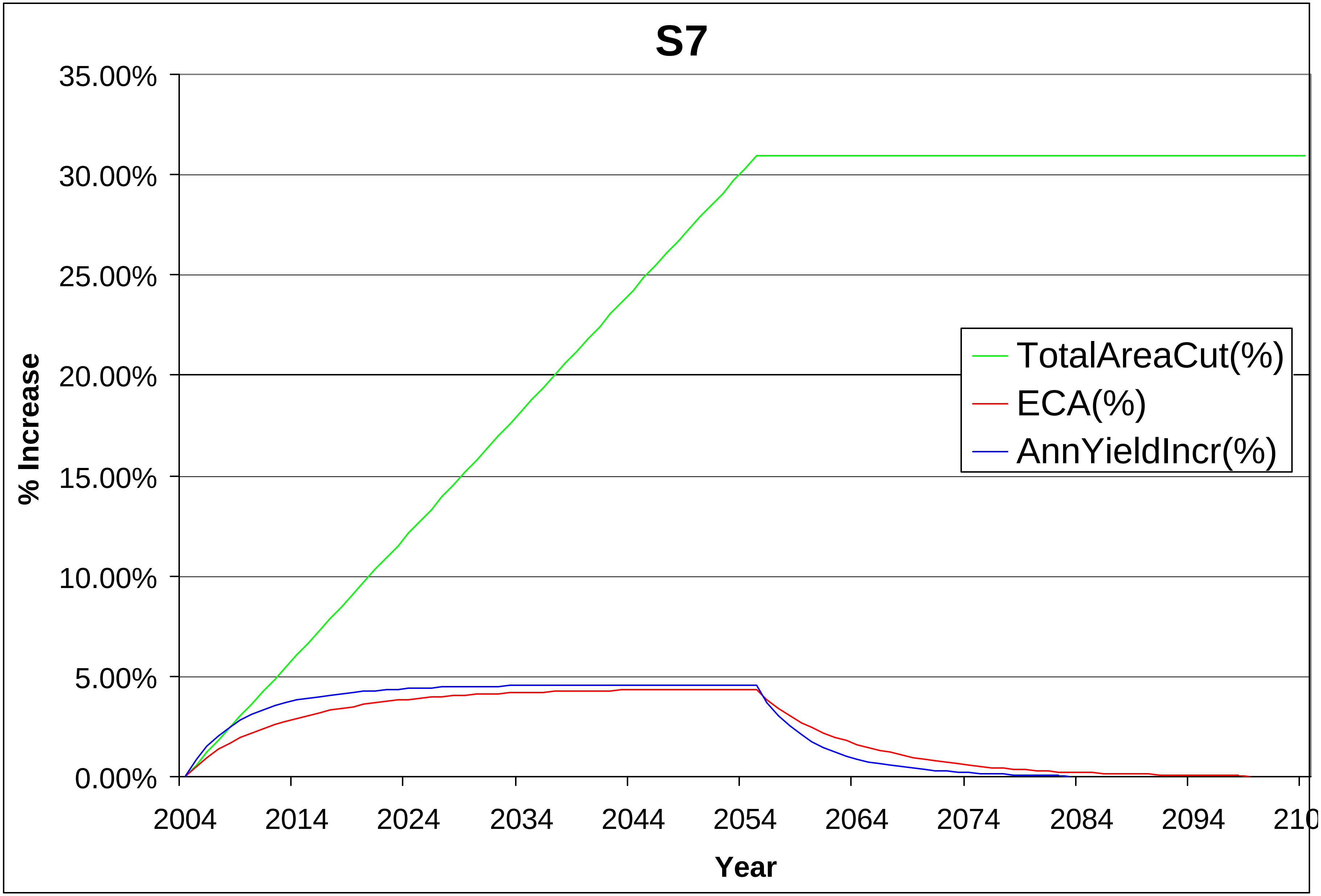
L11						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	3473.0	3050.3	0.33%	0.29%	0.43%	0.3
2006	6945.9	5727.2	0.66%	0.55%	0.79%	0.6
2007	10418.9	8075.5	0.99%	0.77%	1.08%	0.8
2008	13891.8	10135.8	1.33%	0.97%	1.31%	1.0
2009	17364.8	11944.6	1.66%	1.14%	1.50%	1.2
2010	20837.8	13534.8	1.99%	1.29%	1.66%	1.3
2011	24310.7	14935.4	2.32%	1.43%	1.78%	1.4
2012	27783.7	16172.2	2.65%	1.54%	1.89%	1.5
2013	31256.6	17267.7	2.98%	1.65%	1.97%	1.5
2014	34729.6	18241.6	3.31%	1.74%	2.04%	1.6
2015	38202.6	19110.6	3.65%	1.82%	2.09%	1.6
2016	41675.5	19889.2	3.98%	1.90%	2.13%	1.7
2017	45148.5	20589.3	4.31%	1.97%	2.17%	1.7
2018	48621.4	21220.9	4.64%	2.03%	2.20%	1.7
2019	52094.4	21779.3	4.97%	2.08%	2.23%	1.7
2020	55567.4	22274.2	5.30%	2.13%	2.26%	1.8
2021	59040.3	22715.2	5.64%	2.17%	2.28%	1.8
2022	62513.3	23109.0	5.97%	2.21%	2.30%	1.8
2023	65986.2	23460.8	6.30%	2.24%	2.32%	1.8
2024	69459.2	23774.5	6.63%	2.27%	2.33%	1.8
2025	72932.2	24053.7	6.96%	2.30%	2.35%	1.8
2026	76405.1	24302.1	7.29%	2.32%	2.36%	1.8
2027	79878.1	24525.3	7.62%	2.34%	2.37%	1.8
2028	83351.0	24726.8	7.96%	2.36%	2.37%	1.9
2029	86824.0	24909.0	8.29%	2.38%	2.38%	1.9
2030	90297.0	25074.1	8.62%	2.39%	2.39%	1.9
2031	93769.9	25224.3	8.95%	2.41%	2.39%	1.9
2032	97242.9	25361.2	9.28%	2.42%	2.40%	1.9
2033	100715.8	25487.6	9.61%	2.43%	2.40%	1.9
2034	104188.8	25604.4	9.94%	2.44%	2.40%	1.9
2035	107661.8	25712.0	10.28%	2.45%	2.40%	1.9
2036	111134.7	25810.8	10.61%	2.46%	2.40%	1.9
2037	114607.7	25901.2	10.94%	2.47%	**2.41%**	1.9
2038	118080.6	25983.9	11.27%	2.48%	**2.41%**	1.9
2039	121553.6	26059.2	11.60%	2.49%	**2.41%**	1.9
2040	125026.6	26127.6	11.93%	2.49%	**2.41%**	1.9
2041	128499.5	26189.6	12.27%	2.50%	**2.41%**	1.9
2042	131972.5	26245.6	12.60%	2.51%	**2.41%**	1.9
2043	135445.4	26296.3	12.93%	2.51%	**2.41%**	1.9
2044	138918.4	26341.9	13.26%	2.51%	**2.41%**	1.9
2045	142391.4	26383.0	13.59%	2.52%	**2.41%**	1.9
2046	145864.3	26426.7	13.92%	2.52%	**2.41%**	1.9
2047	149337.3	26466.5	14.25%	2.53%	**2.41%**	1.9
2048	152810.2	26502.5	14.59%	2.53%	**2.41%**	1.9
2049	156283.2	26534.8	14.92%	2.53%	**2.41%**	1.9
2050	159756.2	26563.7	15.25%	**2.54%**	**2.41%**	1.9
2051	163229.1	26589.1	15.58%	**2.54%**	**2.41%**	1.9
2052	166702.1	26611.2	15.91%	**2.54%**	**2.41%**	1.9
2053	170175.0	26630.2	16.24%	**2.54%**	**2.41%**	1.9
2054	173648.0	26646.2	16.57%	**2.54%**	**2.41%**	1.9
2055	177121.0	26659.4	16.91%	**2.54%**	**2.41%**	1.9
2056	177121.0	23619.6	16.91%	2.25%	1.98%	1.5
2057	177121.0	20950.8	16.91%	2.00%	1.63%	1.3
2058	177121.0	18608.3	16.91%	1.78%	1.34%	1.0
2059	177121.0	16551.9	16.91%	1.58%	1.10%	0.9
2060	177121.0	14745.2	16.91%	1.41%	0.91%	0.7
2061	177121.0	13156.1	16.91%	1.26%	0.75%	0.6
2062	177121.0	11755.6	16.91%	1.12%	0.63%	0.5
2063	177121.0	10518.8	16.91%	1.00%	0.53%	0.4
2064	177121.0	9423.3	16.91%	0.90%	0.44%	0.3
2065	177121.0	8449.8	16.91%	0.81%	0.38%	0.3
2066	177121.0	7582.4	16.91%	0.72%	0.32%	0.3
2067	177121.0	6803.8	16.91%	0.65%	0.28%	0.2
2068	177121.0	6103.7	16.91%	0.58%	0.24%	0.2
2069	177121.0	5472.2	16.91%	0.52%	0.21%	0.2
2070	177121.0	4913.8	16.91%	0.47%	0.18%	0.1
2071	177121.0	4418.8	16.91%	0.42%	0.15%	0.1
2072	177121.0	3977.9	16.91%	0.38%	0.13%	0.1
2073	177121.0	3584.1	16.91%	0.34%	0.11%	0.1
2074	177121.0	3232.3	16.91%	0.31%	0.10%	0.1
2075	177121.0	2918.6	16.91%	0.28%	0.08%	0.1
2076	177121.0	2639.4	16.91%	0.25%	0.07%	0.1
2077	177121.0	2391.0	16.91%	0.23%	0.06%	0.0
2078	177121.0	2167.8	16.91%	0.21%	0.05%	0.0
2079	177121.0	1966.3	16.91%	0.19%	0.04%	0.0
2080	177121.0	1784.1	16.91%	0.17%	0.03%	0.0
2081	177121.0	1618.9	16.91%	0.15%	0.02%	0.0
2082	177121.0	1468.8	16.91%	0.14%	0.02%	0.0
2083	177121.0	1331.9	16.91%	0.13%	0.02%	0.0
2084	177121.0	1205.4	16.91%	0.12%	0.01%	0.0
2085	177121.0	1088.6	16.91%	0.10%	0.01%	0.0
2086	177121.0	981.1	16.91%	0.09%	0.01%	0.0
2087	177121.0	882.3	16.91%	0.08%	0.01%	0.0
2088	177121.0	791.8	16.91%	0.08%	0.01%	0.0
2089	177121.0	709.2	16.91%	0.07%	0.01%	0.0
2090	177121.0	633.9	16.91%	0.06%	0.01%	0.0
2091	177121.0	565.5	16.91%	0.05%	0.00%	0.0
2092	177121.0	503.5	16.91%	0.05%	0.00%	0.0
2093	177121.0	447.4	16.91%	0.04%	0.00%	0.0
2094	177121.0	396.8	16.91%	0.04%	0.00%	0.0
2095	177121.0	351.1	16.91%	0.03%	0.00%	0.0
2096	177121.0	310.1	16.91%	0.03%	0.00%	0.0
2097	177121.0	266.4	16.91%	0.03%	0.00%	0.0
2098	177121.0	226.6	16.91%	0.02%	0.00%	0.0
2099	177121.0	190.6	16.91%	0.02%	0.00%	0.0
2100	177121.0	158.2	16.91%	0.02%	0.00%	0.0
2101	177121.0	129.4	16.91%	0.01%	0.00%	0.0
2102	177121.0	104.0	16.91%	0.01%	0.00%	0.0
2103	177121.0	81.8	16.91%	0.01%	0.00%	0.0
2104	177121.0	62.8	16.91%	0.01%	0.00%	0.0


A14
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

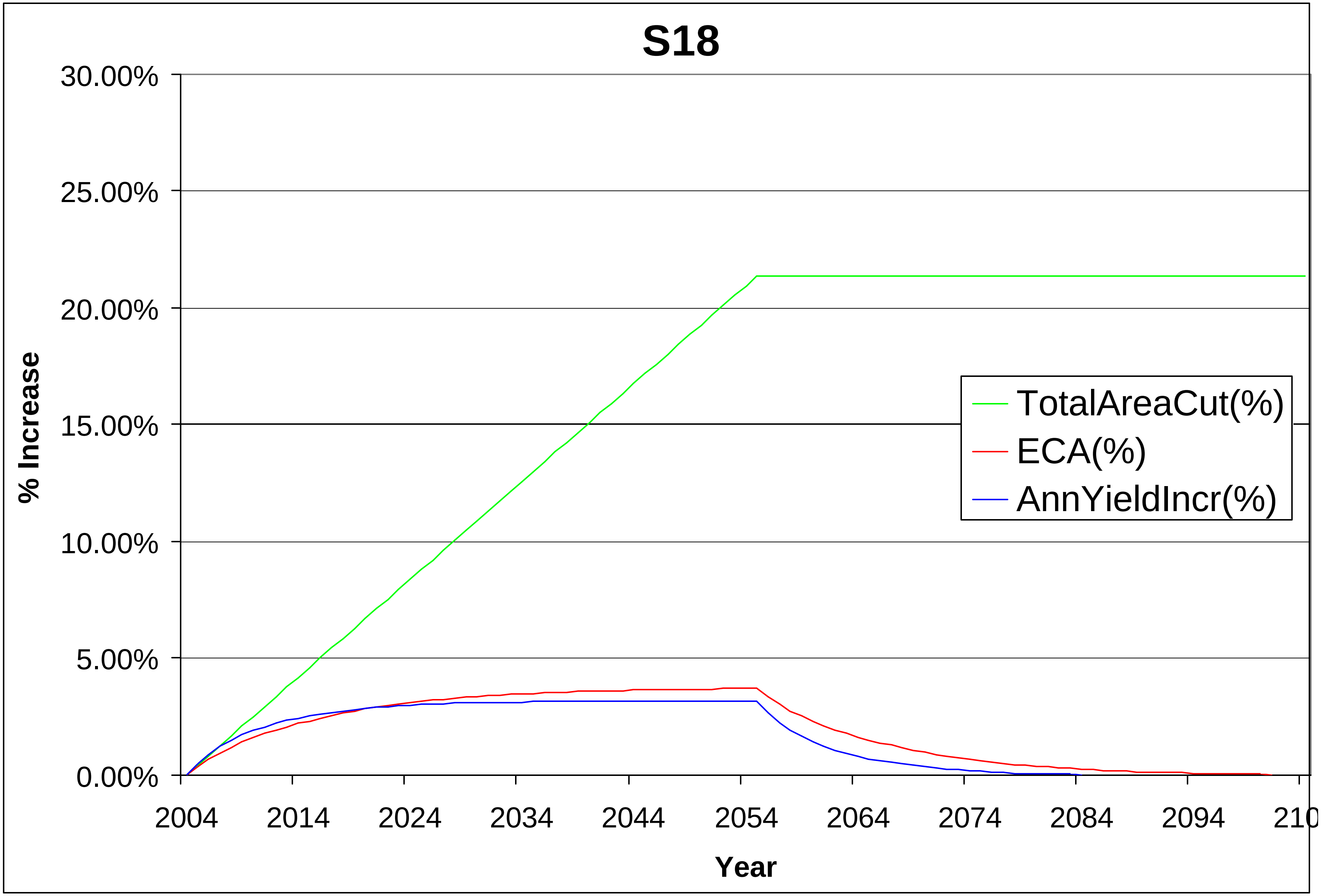
A14						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	3248.3	2917.6	0.28%	0.25%	0.21%	0.3
2006	6496.5	5539.1	0.55%	0.47%	0.39%	0.5
2007	9744.8	7895.9	0.83%	0.67%	0.54%	0.7
2008	12993.0	10017.1	1.11%	0.85%	0.67%	0.8
2009	16241.3	11928.7	1.38%	1.02%	0.78%	0.9
2010	19489.5	13654.5	1.66%	1.16%	0.87%	1.0
2011	22737.8	15215.8	1.94%	1.30%	0.95%	1.1
2012	25986.0	16631.6	2.21%	1.42%	1.01%	1.2
2013	29234.3	17919.0	2.49%	1.53%	1.07%	1.3
2014	32482.5	19092.8	2.77%	1.63%	1.12%	1.3
2015	35730.8	20166.1	3.04%	1.72%	1.16%	1.4
2016	38979.0	21150.4	3.32%	1.80%	1.19%	1.4
2017	42227.3	22055.1	3.60%	1.88%	1.23%	1.5
2018	45475.5	22888.7	3.87%	1.95%	1.25%	1.5
2019	48723.8	23647.6	4.15%	2.01%	1.28%	1.5
2020	51972.0	24341.2	4.43%	2.07%	1.30%	1.6
2021	55220.3	24977.6	4.70%	2.13%	1.32%	1.6
2022	58468.5	25562.6	4.98%	2.18%	1.34%	1.6
2023	61716.8	26100.5	5.26%	2.22%	1.36%	1.6
2024	64965.0	26594.7	5.53%	2.27%	1.37%	1.6
2025	68213.3	27047.9	5.81%	2.30%	1.38%	1.7
2026	71461.5	27463.6	6.09%	2.34%	1.39%	1.7
2027	74709.8	27846.5	6.36%	2.37%	1.40%	1.7
2028	77958.0	28199.8	6.64%	2.40%	1.41%	1.7
2029	81206.3	28525.5	6.92%	2.43%	1.42%	1.7
2030	84454.6	28825.9	7.19%	2.46%	1.42%	1.7
2031	87702.8	29102.8	7.47%	2.48%	1.43%	1.7
2032	90951.1	29358.0	7.75%	2.50%	1.43%	1.7
2033	94199.3	29594.1	8.02%	2.52%	1.43%	1.7
2034	97447.6	29812.2	8.30%	2.54%	1.44%	1.7
2035	100695.8	30013.0	8.58%	2.56%	1.44%	1.7
2036	103944.1	30197.4	8.85%	2.57%	1.44%	1.7
2037	107192.3	30366.3	9.13%	2.59%	1.44%	1.7
2038	110440.6	30520.6	9.41%	2.60%	1.44%	1.7
2039	113688.8	30661.1	9.68%	2.61%	1.44%	1.7
2040	116937.1	30788.8	9.96%	2.62%	1.44%	1.7
2041	120185.3	30904.6	10.24%	2.63%	1.44%	1.7
2042	123433.6	31009.3	10.51%	2.64%	1.44%	1.7
2043	126681.8	31103.8	10.79%	2.65%	1.44%	1.7
2044	129930.1	31189.0	11.07%	2.66%	1.44%	1.7
2045	133178.3	31265.7	11.34%	2.66%	1.44%	1.7
2046	136426.6	31347.2	11.62%	2.67%	1.44%	1.7
2047	139674.8	31421.5	11.90%	2.68%	1.44%	1.7
2048	142923.1	31488.7	12.17%	2.68%	1.44%	1.7
2049	146171.3	31549.1	12.45%	2.69%	**1.45%**	1.7
2050	149419.6	31603.0	12.73%	2.69%	**1.45%**	1.7
2051	152667.8	31650.5	13.00%	2.70%	**1.45%**	1.7
2052	155916.1	31691.8	13.28%	2.70%	**1.45%**	1.7
2053	159164.3	31727.3	13.56%	2.70%	**1.45%**	1.7
2054	162412.6	31757.1	13.83%	**2.71%**	**1.45%**	1.7
2055	165660.9	31781.7	14.11%	**2.71%**	**1.45%**	1.7
2056	165660.9	28883.7	14.11%	2.46%	1.23%	1.5
2057	165660.9	26277.2	14.11%	2.24%	1.05%	1.3
2058	165660.9	23931.2	14.11%	2.04%	0.90%	1.1
2059	165660.9	21817.3	14.11%	1.86%	0.78%	0.9
2060	165660.9	19909.9	14.11%	1.70%	0.67%	0.8
2061	165660.9	18186.0	14.11%	1.55%	0.58%	0.7
2062	165660.9	16624.9	14.11%	1.42%	0.50%	0.6
2063	165660.9	15209.0	14.11%	1.30%	0.43%	0.5
2064	165660.9	13921.7	14.11%	1.19%	0.38%	0.5
2065	165660.9	12748.6	14.11%	1.09%	0.33%	0.4
2066	165660.9	11678.4	14.11%	0.99%	0.29%	0.3
2067	165660.9	10694.2	14.11%	0.91%	0.25%	0.3
2068	165660.9	9789.4	14.11%	0.83%	0.22%	0.3
2069	165660.9	8955.8	14.11%	0.76%	0.19%	0.2
2070	165660.9	8196.9	14.11%	0.70%	0.17%	0.2
2071	165660.9	7503.3	14.11%	0.64%	0.14%	0.2
2072	165660.9	6866.9	14.11%	0.58%	0.12%	0.1
2073	165660.9	6281.9	14.11%	0.54%	0.11%	0.1
2074	165660.9	5744.0	14.11%	0.49%	0.09%	0.1
2075	165660.9	5249.9	14.11%	0.45%	0.08%	0.1
2076	165660.9	4796.6	14.11%	0.41%	0.06%	0.1
2077	165660.9	4381.0	14.11%	0.37%	0.05%	0.1
2078	165660.9	3998.0	14.11%	0.34%	0.04%	0.1
2079	165660.9	3644.8	14.11%	0.31%	0.04%	0.0
2080	165660.9	3319.0	14.11%	0.28%	0.03%	0.0
2081	165660.9	3018.6	14.11%	0.26%	0.02%	0.0
2082	165660.9	2741.7	14.11%	0.23%	0.02%	0.0
2083	165660.9	2486.5	14.11%	0.21%	0.02%	0.0
2084	165660.9	2250.4	14.11%	0.19%	0.01%	0.0
2085	165660.9	2032.3	14.11%	0.17%	0.01%	0.0
2086	165660.9	1831.5	14.11%	0.16%	0.01%	0.0
2087	165660.9	1647.1	14.11%	0.14%	0.01%	0.0
2088	165660.9	1478.2	14.11%	0.13%	0.01%	0.0
2089	165660.9	1323.9	14.11%	0.11%	0.01%	0.0
2090	165660.9	1183.4	14.11%	0.10%	0.00%	0.0
2091	165660.9	1055.7	14.11%	0.09%	0.00%	0.0
2092	165660.9	939.9	14.11%	0.08%	0.00%	0.0
2093	165660.9	835.2	14.11%	0.07%	0.00%	0.0
2094	165660.9	740.7	14.11%	0.06%	0.00%	0.0
2095	165660.9	655.5	14.11%	0.06%	0.00%	0.0
2096	165660.9	578.8	14.11%	0.05%	0.00%	0.0
2097	165660.9	497.3	14.11%	0.04%	0.00%	0.0
2098	165660.9	423.0	14.11%	0.04%	0.00%	0.0
2099	165660.9	355.8	14.11%	0.03%	0.00%	0.0
2100	165660.9	295.4	14.11%	0.03%	0.00%	0.0
2101	165660.9	241.5	14.11%	0.02%	0.00%	0.0
2102	165660.9	194.1	14.11%	0.02%	0.00%	0.0
2103	165660.9	152.7	14.11%	0.01%	0.00%	0.0
2104	165660.9	117.2	14.11%	0.01%	0.00%	0.0


L3
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year

L3						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	1429.3	1300.7	0.24%	0.22%	0.23%	0.2
2006	2858.6	2488.8	0.49%	0.42%	0.42%	0.5
2007	4287.9	3578.6	0.73%	0.61%	0.59%	0.6
2008	5717.2	4582.5	0.97%	0.78%	0.74%	0.8
2009	7146.5	5511.5	1.22%	0.94%	0.88%	0.9
2010	8575.8	6375.2	1.46%	1.09%	1.00%	1.1
2011	10005.2	7181.7	1.70%	1.22%	1.10%	1.2
2012	11434.5	7937.8	1.95%	1.35%	1.20%	1.3
2013	12863.8	8649.4	2.19%	1.47%	1.28%	1.4
2014	14293.1	9321.1	2.43%	1.59%	1.36%	1.5
2015	15722.4	9956.6	2.68%	1.70%	1.43%	1.5
2016	17151.7	10558.9	2.92%	1.80%	1.49%	1.6
2017	18581.0	11130.2	3.16%	1.89%	1.55%	1.7
2018	20010.3	11671.9	3.41%	1.99%	1.60%	1.7
2019	21439.6	12182.3	3.65%	2.07%	1.64%	1.8
2020	22868.9	12661.6	3.89%	2.16%	1.69%	1.8
2021	24298.2	13111.2	4.14%	2.23%	1.72%	1.9
2022	25727.5	13532.6	4.38%	2.30%	1.76%	1.9
2023	27156.9	13926.9	4.62%	2.37%	1.79%	1.9
2024	28586.2	14295.4	4.87%	2.43%	1.81%	2.0
2025	30015.5	14639.0	5.11%	2.49%	1.84%	2.0
2026	31444.8	14959.1	5.35%	2.55%	1.86%	2.0
2027	32874.1	15257.1	5.60%	2.60%	1.87%	2.0
2028	34303.4	15534.3	5.84%	2.64%	1.89%	2.0
2029	35732.7	15791.7	6.08%	2.69%	1.90%	2.1
2030	37162.0	16030.4	6.33%	2.73%	1.91%	2.1
2031	38591.3	16251.6	6.57%	2.77%	1.92%	2.1
2032	40020.6	16456.2	6.81%	2.80%	1.93%	2.1
2033	41449.9	16645.5	7.06%	2.83%	1.93%	2.1
2034	42879.2	16820.4	7.30%	2.86%	1.94%	2.1
2035	44308.5	16981.4	7.54%	2.89%	1.94%	2.1
2036	45737.9	17129.3	7.79%	2.92%	1.94%	2.1
2037	47167.2	17264.8	8.03%	2.94%	1.94%	2.1
2038	48596.5	17388.5	8.27%	2.96%	1.94%	2.1
2039	50025.8	17501.2	8.52%	2.98%	1.95%	2.1
2040	51455.1	17603.6	8.76%	3.00%	1.95%	2.1
2041	52884.4	17696.4	9.00%	3.01%	1.95%	2.1
2042	54313.7	17780.4	9.25%	3.03%	1.95%	2.1
2043	55743.0	17856.2	9.49%	3.04%	1.95%	2.1
2044	57172.3	17924.5	9.73%	3.05%	1.95%	2.1
2045	58601.6	17986.0	9.98%	3.06%	1.95%	2.1
2046	60030.9	18051.4	10.22%	3.07%	1.95%	2.1
2047	61460.2	18111.0	10.46%	3.08%	1.95%	2.1
2048	62889.6	18164.9	10.71%	3.09%	1.95%	2.1
2049	64318.9	18213.3	10.95%	3.10%	1.95%	2.1
2050	65748.2	18256.5	11.19%	3.11%	1.95%	2.1
2051	67177.5	18294.6	11.44%	3.11%	1.95%	2.1
2052	68606.8	18327.7	11.68%	3.12%	1.95%	2.1
2053	70036.1	18356.2	11.92%	**3.13%**	1.95%	2.1
2054	71465.4	18380.1	12.17%	**3.13%**	**1.96%**	2.1
2055	72894.7	18399.8	12.41%	**3.13%**	**1.96%**	2.1
2056	72894.7	17114.8	12.41%	2.91%	1.73%	1.9
2057	72894.7	15938.7	12.41%	2.71%	1.53%	1.7
2058	72894.7	14857.7	12.41%	2.53%	1.36%	1.5
2059	72894.7	13859.6	12.41%	2.36%	1.21%	1.3
2060	72894.7	12934.0	12.41%	2.20%	1.08%	1.2
2061	72894.7	12071.8	12.41%	2.06%	0.96%	1.0
2062	72894.7	11265.4	12.41%	1.92%	0.85%	0.9
2063	72894.7	10509.3	12.41%	1.79%	0.76%	0.8
2064	72894.7	9797.7	12.41%	1.67%	0.67%	0.7
2065	72894.7	9126.6	12.41%	1.55%	0.60%	0.6
2066	72894.7	8493.6	12.41%	1.45%	0.53%	0.6
2067	72894.7	7891.3	12.41%	1.34%	0.46%	0.5
2068	72894.7	7320.1	12.41%	1.25%	0.41%	0.4
2069	72894.7	6778.3	12.41%	1.15%	0.36%	0.4
2070	72894.7	6267.9	12.41%	1.07%	0.31%	0.3
2071	72894.7	5788.6	12.41%	0.99%	0.27%	0.3
2072	72894.7	5339.0	12.41%	0.91%	0.23%	0.3
2073	72894.7	4917.6	12.41%	0.84%	0.20%	0.2
2074	72894.7	4523.3	12.41%	0.77%	0.17%	0.2
2075	72894.7	4154.9	12.41%	0.71%	0.14%	0.2
2076	72894.7	3811.2	12.41%	0.65%	0.12%	0.1
2077	72894.7	3491.1	12.41%	0.59%	0.10%	0.1
2078	72894.7	3193.1	12.41%	0.54%	0.08%	0.1
2079	72894.7	2915.9	12.41%	0.50%	0.07%	0.1
2080	72894.7	2658.5	12.41%	0.45%	0.05%	0.1
2081	72894.7	2419.8	12.41%	0.41%	0.04%	0.0
2082	72894.7	2198.6	12.41%	0.37%	0.04%	0.0
2083	72894.7	1994.1	12.41%	0.34%	0.03%	0.0
2084	72894.7	1804.7	12.41%	0.31%	0.02%	0.0
2085	72894.7	1629.8	12.41%	0.28%	0.02%	0.0
2086	72894.7	1468.8	12.41%	0.25%	0.02%	0.0
2087	72894.7	1320.9	12.41%	0.22%	0.01%	0.0
2088	72894.7	1185.5	12.41%	0.20%	0.01%	0.0
2089	72894.7	1061.7	12.41%	0.18%	0.01%	0.0
2090	72894.7	949.0	12.41%	0.16%	0.01%	0.0
2091	72894.7	846.6	12.41%	0.14%	0.01%	0.0
2092	72894.7	753.8	12.41%	0.13%	0.01%	0.0
2093	72894.7	669.8	12.41%	0.11%	0.01%	0.0
2094	72894.7	594.0	12.41%	0.10%	0.01%	0.0
2095	72894.7	525.7	12.41%	0.09%	0.00%	0.0
2096	72894.7	464.2	12.41%	0.08%	0.00%	0.0
2097	72894.7	398.8	12.41%	0.07%	0.00%	0.0
2098	72894.7	339.2	12.41%	0.06%	0.00%	0.0
2099	72894.7	285.3	12.41%	0.05%	0.00%	0.0
2100	72894.7	236.9	12.41%	0.04%	0.00%	0.0
2101	72894.7	193.7	12.41%	0.03%	0.00%	0.0
2102	72894.7	155.6	12.41%	0.03%	0.00%	0.0
2103	72894.7	122.5	12.41%	0.02%	0.00%	0.0
2104	72894.7	94.0	12.41%	0.02%	0.00%	0.0


S7
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
210
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

S7						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	739.8	631.9	0.61%	0.52%	0.84%	0.7
2006	1479.6	1171.9	1.21%	0.96%	1.51%	1.2
2007	2219.4	1634.1	1.82%	1.34%	2.04%	1.7
2008	2959.2	2031.1	2.43%	1.66%	2.47%	2.0
2009	3699.0	2373.6	3.03%	1.95%	2.82%	2.3
2010	4438.8	2671.2	3.64%	2.19%	3.10%	2.5
2011	5178.7	2931.8	4.24%	2.40%	3.33%	2.7
2012	5918.5	3162.2	4.85%	2.59%	3.51%	2.9
2013	6658.3	3368.0	5.46%	2.76%	3.67%	3.0
2014	7398.1	3553.7	6.06%	2.91%	3.80%	3.1
2015	8137.9	3722.9	6.67%	3.05%	3.91%	3.2
2016	8877.7	3878.2	7.28%	3.18%	4.00%	3.3
2017	9617.5	4021.8	7.88%	3.30%	4.07%	3.3
2018	10357.3	4154.8	8.49%	3.41%	4.14%	3.4
2019	11097.1	4275.8	9.09%	3.50%	4.19%	3.4
2020	11836.9	4384.5	9.70%	3.59%	4.24%	3.5
2021	12576.7	4481.9	10.31%	3.67%	4.29%	3.5
2022	13316.5	4569.1	10.91%	3.74%	4.32%	3.5
2023	14056.4	4647.0	11.52%	3.81%	4.36%	3.6
2024	14796.2	4716.4	12.13%	3.87%	4.39%	3.6
2025	15536.0	4778.1	12.73%	3.92%	4.41%	3.6
2026	16275.8	4832.9	13.34%	3.96%	4.44%	3.6
2027	17015.6	4881.8	13.94%	4.00%	4.46%	3.7
2028	17755.4	4925.4	14.55%	4.04%	4.47%	3.7
2029	18495.2	4964.5	15.16%	4.07%	4.49%	3.7
2030	19235.0	4999.7	15.76%	4.10%	4.50%	3.7
2031	19974.8	5031.4	16.37%	4.12%	4.51%	3.7
2032	20714.6	5060.2	16.98%	4.15%	4.51%	3.7
2033	21454.4	5086.7	17.58%	4.17%	4.52%	3.7
2034	22194.2	5111.3	18.19%	4.19%	4.52%	3.7
2035	22934.0	5133.9	18.80%	4.21%	4.53%	3.7
2036	23673.9	5154.6	19.40%	4.22%	4.53%	3.7
2037	24413.7	5173.6	20.01%	4.24%	4.53%	3.7
2038	25153.5	5191.0	20.61%	4.25%	4.53%	3.7
2039	25893.3	5206.8	21.22%	4.27%	4.54%	3.7
2040	26633.1	5221.1	21.83%	4.28%	4.54%	3.7
2041	27372.9	5234.2	22.43%	4.29%	4.54%	3.7
2042	28112.7	5245.9	23.04%	4.30%	4.54%	3.7
2043	28852.5	5256.6	23.65%	4.31%	4.54%	3.7
2044	29592.3	5266.2	24.25%	4.32%	4.54%	3.7
2045	30332.1	5274.8	24.86%	4.32%	4.54%	3.7
2046	31071.9	5284.0	25.46%	4.33%	4.54%	3.7
2047	31811.7	5292.3	26.07%	4.34%	4.54%	3.7
2048	32551.6	5299.9	26.68%	4.34%	4.54%	3.7
2049	33291.4	5306.7	27.28%	4.35%	4.54%	3.7
2050	34031.2	5312.7	27.89%	4.35%	4.54%	3.7
2051	34771.0	5318.1	28.50%	4.36%	4.54%	3.7
2052	35510.8	5322.7	29.10%	4.36%	4.54%	3.7
2053	36250.6	5326.7	29.71%	**4.37%**	**4.55%**	3.7
2054	36990.4	5330.1	30.31%	**4.37%**	**4.55%**	3.7
2055	37730.2	5332.8	30.92%	**4.37%**	**4.55%**	3.7
2056	37730.2	4703.1	30.92%	3.85%	3.71%	3.0
2057	37730.2	4164.9	30.92%	3.41%	3.04%	2.5
2058	37730.2	3703.9	30.92%	3.04%	2.50%	2.1
2059	37730.2	3307.7	30.92%	2.71%	2.07%	1.7
2060	37730.2	2965.6	30.92%	2.43%	1.73%	1.4
2061	37730.2	2668.3	30.92%	2.19%	1.45%	1.2
2062	37730.2	2407.7	30.92%	1.97%	1.22%	1.0
2063	37730.2	2177.2	30.92%	1.78%	1.03%	0.8
2064	37730.2	1971.4	30.92%	1.62%	0.88%	0.7
2065	37730.2	1785.8	30.92%	1.46%	0.75%	0.6
2066	37730.2	1617.0	30.92%	1.33%	0.64%	0.5
2067	37730.2	1461.7	30.92%	1.20%	0.55%	0.5
2068	37730.2	1318.1	30.92%	1.08%	0.47%	0.4
2069	37730.2	1185.1	30.92%	0.97%	0.41%	0.3
2070	37730.2	1064.1	30.92%	0.87%	0.35%	0.3
2071	37730.2	955.4	30.92%	0.78%	0.30%	0.2
2072	37730.2	858.0	30.92%	0.70%	0.26%	0.2
2073	37730.2	770.8	30.92%	0.63%	0.22%	0.2
2074	37730.2	692.9	30.92%	0.57%	0.19%	0.2
2075	37730.2	623.5	30.92%	0.51%	0.16%	0.1
2076	37730.2	561.8	30.92%	0.46%	0.13%	0.1
2077	37730.2	507.0	30.92%	0.42%	0.11%	0.1
2078	37730.2	458.1	30.92%	0.38%	0.09%	0.1
2079	37730.2	414.5	30.92%	0.34%	0.07%	0.1
2080	37730.2	375.4	30.92%	0.31%	0.06%	0.0
2081	37730.2	340.2	30.92%	0.28%	0.05%	0.0
2082	37730.2	308.5	30.92%	0.25%	0.04%	0.0
2083	37730.2	279.7	30.92%	0.23%	0.03%	0.0
2084	37730.2	253.2	30.92%	0.21%	0.03%	0.0
2085	37730.2	228.6	30.92%	0.19%	0.02%	0.0
2086	37730.2	206.0	30.92%	0.17%	0.02%	0.0
2087	37730.2	185.3	30.92%	0.15%	0.02%	0.0
2088	37730.2	166.3	30.92%	0.14%	0.01%	0.0
2089	37730.2	148.9	30.92%	0.12%	0.01%	0.0
2090	37730.2	133.1	30.92%	0.11%	0.01%	0.0
2091	37730.2	118.8	30.92%	0.10%	0.01%	0.0
2092	37730.2	105.7	30.92%	0.09%	0.01%	0.0
2093	37730.2	94.0	30.92%	0.08%	0.01%	0.0
2094	37730.2	83.3	30.92%	0.07%	0.01%	0.0
2095	37730.2	73.7	30.92%	0.06%	0.00%	0.0
2096	37730.2	65.1	30.92%	0.05%	0.00%	0.0
2097	37730.2	55.9	30.92%	0.05%	0.00%	0.0
2098	37730.2	47.6	30.92%	0.04%	0.00%	0.0
2099	37730.2	40.0	30.92%	0.03%	0.00%	0.0
2100	37730.2	33.2	30.92%	0.03%	0.00%	0.0
2101	37730.2	27.2	30.92%	0.02%	0.00%	0.0
2102	37730.2	21.8	30.92%	0.02%	0.00%	0.0
2103	37730.2	17.2	30.92%	0.01%	0.00%	0.0
2104	37730.2	13.2	30.92%	0.01%	0.00%	0.0


S18
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
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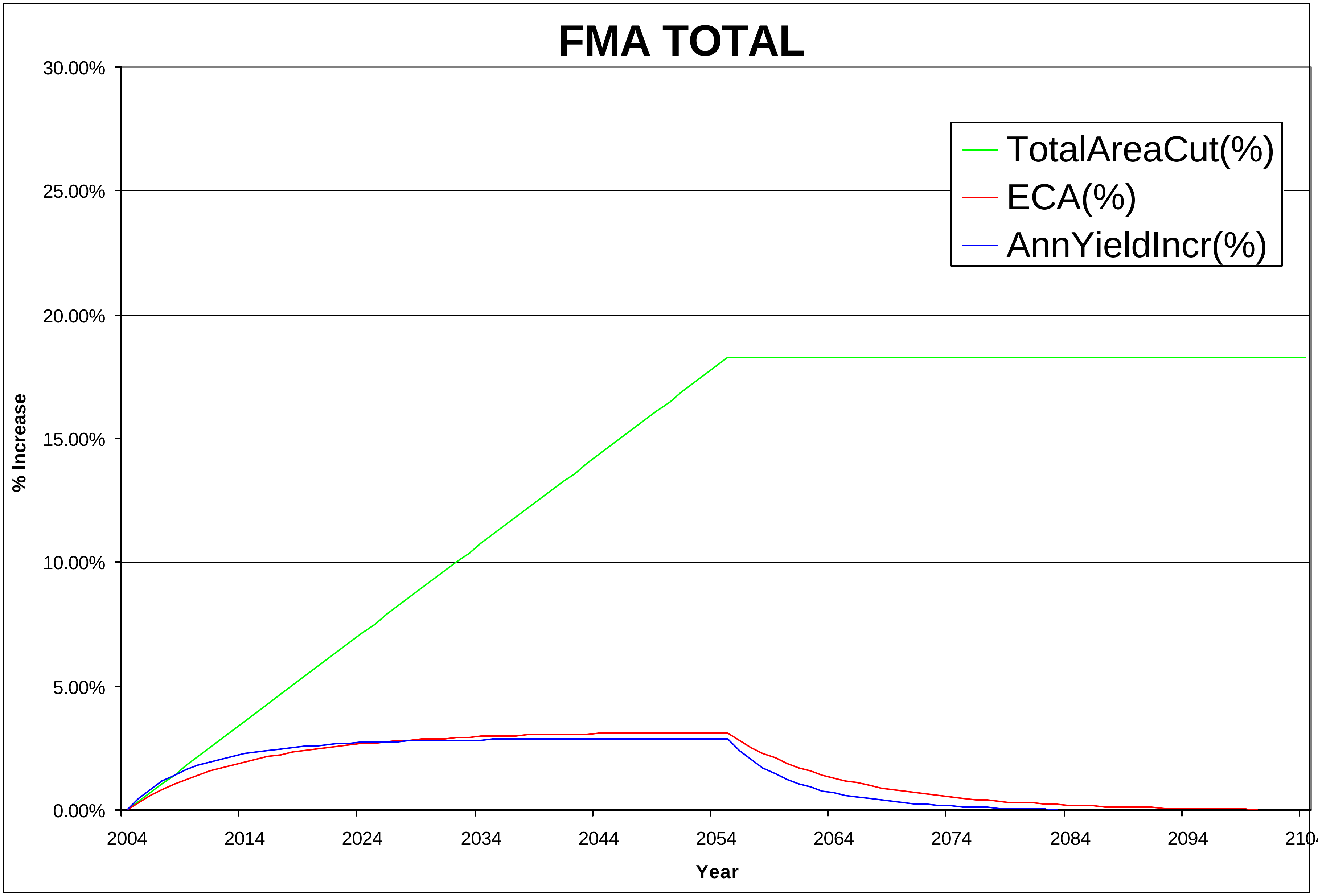
2064
2074
2084
2094
210
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

S18						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	2524.6	2191.2	0.42%	0.36%	0.49%	0.4
2006	5049.3	4098.0	0.84%	0.68%	0.89%	0.7
2007	7573.9	5763.7	1.26%	0.96%	1.22%	1.0
2008	10098.5	7226.4	1.68%	1.20%	1.50%	1.3
2009	12623.1	8519.2	2.10%	1.41%	1.72%	1.4
2010	15147.8	9670.6	2.51%	1.61%	1.92%	1.6
2011	17672.4	10704.9	2.93%	1.78%	2.08%	1.7
2012	20197.0	11642.4	3.35%	1.93%	2.22%	1.9
2013	22721.6	12499.8	3.77%	2.07%	2.34%	2.0
2014	25246.3	13290.5	4.19%	2.21%	2.44%	2.1
2015	27770.9	14025.1	4.61%	2.33%	2.53%	2.1
2016	30295.5	14711.4	5.03%	2.44%	2.61%	2.2
2017	32820.1	15355.0	5.45%	2.55%	2.68%	2.3
2018	35344.8	15959.8	5.87%	2.65%	2.75%	2.3
2019	37869.4	16520.6	6.29%	2.74%	2.80%	2.4
2020	40394.0	17035.9	6.70%	2.83%	2.85%	2.4
2021	42918.6	17508.8	7.12%	2.91%	2.89%	2.4
2022	45443.3	17942.2	7.54%	2.98%	2.93%	2.5
2023	47967.9	18338.8	7.96%	3.04%	2.96%	2.5
2024	50492.5	18701.2	8.38%	3.10%	2.99%	2.5
2025	53017.1	19032.0	8.80%	3.16%	3.02%	2.5
2026	55541.8	19333.7	9.22%	3.21%	3.04%	2.6
2027	58066.4	19609.2	9.64%	3.25%	3.06%	2.6
2028	60591.0	19861.0	10.06%	3.30%	3.08%	2.6
2029	63115.7	20091.2	10.48%	3.33%	3.09%	2.6
2030	65640.3	20302.0	10.90%	3.37%	3.11%	2.6
2031	68164.9	20495.1	11.31%	3.40%	3.12%	2.6
2032	70689.5	20672.3	11.73%	3.43%	3.12%	2.6
2033	73214.2	20836.2	12.15%	3.46%	3.13%	2.6
2034	75738.8	20987.5	12.57%	3.48%	3.13%	2.6
2035	78263.4	21126.8	12.99%	3.51%	3.14%	2.6
2036	80788.0	21254.8	13.41%	3.53%	3.14%	2.6
2037	83312.7	21372.0	13.83%	3.55%	3.14%	2.6
2038	85837.3	21479.0	14.25%	3.57%	3.14%	2.6
2039	88361.9	21576.6	14.67%	3.58%	3.15%	2.6
2040	90886.5	21665.2	15.09%	3.60%	3.15%	2.6
2041	93411.2	21745.5	15.50%	3.61%	3.15%	2.6
2042	95935.8	21818.2	15.92%	3.62%	3.15%	2.6
2043	98460.4	21883.7	16.34%	3.63%	3.15%	2.6
2044	100985.0	21942.9	16.76%	3.64%	3.15%	2.6
2045	103509.7	21996.1	17.18%	3.65%	3.15%	2.6
2046	106034.3	22052.7	17.60%	3.66%	3.15%	2.6
2047	108558.9	22104.2	18.02%	3.67%	3.15%	2.6
2048	111083.5	22150.9	18.44%	3.68%	3.15%	2.6
2049	113608.2	22192.8	18.86%	3.68%	3.15%	2.6
2050	116132.8	22230.1	19.28%	3.69%	3.15%	2.6
2051	118657.4	22263.1	19.70%	3.70%	3.15%	2.7
2052	121182.0	22291.8	20.11%	3.70%	**3.16%**	2.7
2053	123706.7	22316.4	20.53%	3.70%	**3.16%**	2.7
2054	126231.3	22337.1	20.95%	**3.71%**	**3.16%**	2.7
2055	128755.9	22354.1	21.37%	**3.71%**	**3.16%**	2.7
2056	128755.9	20176.5	21.37%	3.35%	2.67%	2.2
2057	128755.9	18280.1	21.37%	3.03%	2.27%	1.9
2058	128755.9	16622.0	21.37%	2.76%	1.93%	1.6
2059	128755.9	15164.3	21.37%	2.52%	1.66%	1.4
2060	128755.9	13874.4	21.37%	2.30%	1.43%	1.2
2061	128755.9	12724.3	21.37%	2.11%	1.24%	1.0
2062	128755.9	11690.1	21.37%	1.94%	1.08%	0.9
2063	128755.9	10752.6	21.37%	1.78%	0.94%	0.8
2064	128755.9	9895.2	21.37%	1.64%	0.82%	0.7
2065	128755.9	9105.0	21.37%	1.51%	0.71%	0.6
2066	128755.9	8372.7	21.37%	1.39%	0.62%	0.5
2067	128755.9	7686.4	21.37%	1.28%	0.54%	0.5
2068	128755.9	7042.7	21.37%	1.17%	0.47%	0.4
2069	128755.9	6438.0	21.37%	1.07%	0.41%	0.3
2070	128755.9	5877.2	21.37%	0.98%	0.36%	0.3
2071	128755.9	5361.9	21.37%	0.89%	0.31%	0.3
2072	128755.9	4889.0	21.37%	0.81%	0.26%	0.2
2073	128755.9	4455.6	21.37%	0.74%	0.23%	0.2
2074	128755.9	4059.0	21.37%	0.67%	0.19%	0.2
2075	128755.9	3696.6	21.37%	0.61%	0.16%	0.1
2076	128755.9	3365.8	21.37%	0.56%	0.13%	0.1
2077	128755.9	3064.0	21.37%	0.51%	0.11%	0.1
2078	128755.9	2788.5	21.37%	0.46%	0.09%	0.1
2079	128755.9	2536.7	21.37%	0.42%	0.08%	0.1
2080	128755.9	2306.5	21.37%	0.38%	0.06%	0.1
2081	128755.9	2095.8	21.37%	0.35%	0.05%	0.0
2082	128755.9	1902.6	21.37%	0.32%	0.04%	0.0
2083	128755.9	1725.4	21.37%	0.29%	0.03%	0.0
2084	128755.9	1561.6	21.37%	0.26%	0.03%	0.0
2085	128755.9	1410.3	21.37%	0.23%	0.02%	0.0
2086	128755.9	1270.9	21.37%	0.21%	0.02%	0.0
2087	128755.9	1143.0	21.37%	0.19%	0.02%	0.0
2088	128755.9	1025.8	21.37%	0.17%	0.01%	0.0
2089	128755.9	918.7	21.37%	0.15%	0.01%	0.0
2090	128755.9	821.2	21.37%	0.14%	0.01%	0.0
2091	128755.9	732.6	21.37%	0.12%	0.01%	0.0
2092	128755.9	652.2	21.37%	0.11%	0.01%	0.0
2093	128755.9	579.6	21.37%	0.10%	0.01%	0.0
2094	128755.9	514.0	21.37%	0.09%	0.01%	0.0
2095	128755.9	454.9	21.37%	0.08%	0.00%	0.0
2096	128755.9	401.7	21.37%	0.07%	0.00%	0.0
2097	128755.9	345.1	21.37%	0.06%	0.00%	0.0
2098	128755.9	293.5	21.37%	0.05%	0.00%	0.0
2099	128755.9	246.9	21.37%	0.04%	0.00%	0.0
2100	128755.9	205.0	21.37%	0.03%	0.00%	0.0
2101	128755.9	167.6	21.37%	0.03%	0.00%	0.0
2102	128755.9	134.7	21.37%	0.02%	0.00%	0.0
2103	128755.9	106.0	21.37%	0.02%	0.00%	0.0
2104	128755.9	81.4	21.37%	0.01%	0.00%	0.0


FMA TOTAL
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
% Increase
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
2104
Year
TotalAreaCut(%)
ECA(%)
AnnYieldIncr(%)

FMA TOTAL						
Year	TotalAreaCut(ha)	ECA(ha)	TotalAreaCut(%)	ECA(%)	AnnYieldIncr(%)	AnnYieldIncr(mm)
2004	0.0	0.0	0.00%	0.00%	0.00%	0.0
2005	24613.4	21663.9	0.36%	0.32%	0.46%	0.4
2006	49226.9	40750.7	0.72%	0.59%	0.83%	0.7
2007	73840.3	57594.9	1.08%	0.84%	1.14%	0.9
2008	98453.7	72495.9	1.43%	1.06%	1.40%	1.2
2009	123067.2	85719.4	1.79%	1.25%	1.62%	1.3
2010	147680.6	97499.6	2.15%	1.42%	1.80%	1.5
2011	172294.0	108041.3	2.51%	1.57%	1.95%	1.6
2012	196907.5	117521.8	2.87%	1.71%	2.07%	1.7
2013	221520.9	126092.9	3.23%	1.84%	2.18%	1.8
2014	246134.3	133883.1	3.58%	1.95%	2.27%	1.9
2015	270747.8	140999.3	3.94%	2.05%	2.35%	1.9
2016	295361.2	147529.3	4.30%	2.15%	2.41%	2.0
2017	319974.6	153543.3	4.66%	2.24%	2.47%	2.1
2018	344588.0	159096.1	5.02%	2.32%	2.52%	2.1
2019	369201.5	164151.0	5.38%	2.39%	2.57%	2.1
2020	393814.9	168745.4	5.74%	2.46%	2.61%	2.2
2021	418428.3	172930.5	6.09%	2.52%	2.64%	2.2
2022	443041.8	176746.0	6.45%	2.57%	2.67%	2.2
2023	467655.2	180223.3	6.81%	2.62%	2.70%	2.2
2024	492268.6	183388.5	7.17%	2.67%	2.73%	2.3
2025	516882.1	186265.9	7.53%	2.71%	2.75%	2.3
2026	541495.5	188880.9	7.89%	2.75%	2.77%	2.3
2027	566108.9	191267.8	8.24%	2.79%	2.78%	2.3
2028	590722.4	193450.6	8.60%	2.82%	2.80%	2.3
2029	615335.8	195447.8	8.96%	2.85%	2.81%	2.3
2030	639949.2	197277.1	9.32%	2.87%	2.82%	2.3
2031	664562.7	198954.4	9.68%	2.90%	2.82%	2.3
2032	689176.1	200493.8	10.04%	2.92%	2.83%	2.3
2033	713789.5	201917.1	10.40%	2.94%	2.84%	2.4
2034	738403.0	203231.6	10.75%	2.96%	2.84%	2.4
2035	763016.4	204442.2	11.11%	2.98%	2.84%	2.4
2036	787629.8	205554.0	11.47%	2.99%	2.84%	2.4
2037	812243.3	206572.2	11.83%	3.01%	2.85%	2.4
2038	836856.7	207502.3	12.19%	3.02%	2.85%	2.4
2039	861470.1	208349.5	12.55%	3.03%	2.85%	2.4
2040	886083.6	209119.4	12.90%	3.05%	2.85%	2.4
2041	910697.0	209817.2	13.26%	3.06%	2.85%	2.4
2042	935310.4	210448.4	13.62%	3.06%	2.85%	2.4
2043	959923.8	211018.2	13.98%	3.07%	2.85%	2.4
2044	984537.3	211531.8	14.34%	3.08%	2.85%	2.4
2045	1009150.7	211994.2	14.70%	3.09%	2.85%	2.4
2046	1033764.1	212485.8	15.06%	3.09%	**2.86%**	2.4
2047	1058377.6	212933.6	15.41%	3.10%	**2.86%**	2.4
2048	1082991.0	213338.8	15.77%	3.11%	**2.86%**	2.4
2049	1107604.4	213703.0	16.13%	3.11%	**2.86%**	2.4
2050	1132217.9	214027.6	16.49%	3.12%	**2.86%**	2.4
2051	1156831.3	214313.8	16.85%	3.12%	**2.86%**	2.4
2052	1181444.7	214563.0	17.21%	3.12%	**2.86%**	2.4
2053	1206058.2	214776.9	17.56%	**3.13%**	**2.86%**	2.4
2054	1230671.6	214956.9	17.92%	**3.13%**	**2.86%**	2.4
2055	1255285.0	215104.9	18.28%	**3.13%**	**2.86%**	2.4
2056	1255285.0	193559.0	18.28%	2.82%	2.40%	2.0
2057	1255285.0	174562.8	18.28%	2.54%	2.03%	1.7
2058	1255285.0	157784.1	18.28%	2.30%	1.71%	1.4
2059	1255285.0	142926.8	18.28%	2.08%	1.45%	1.2
2060	1255285.0	129728.7	18.28%	1.89%	1.24%	1.0
2061	1255285.0	117959.5	18.28%	1.72%	1.06%	0.9
2062	1255285.0	107418.9	18.28%	1.56%	0.91%	0.8
2063	1255285.0	97938.4	18.28%	1.43%	0.79%	0.7
2064	1255285.0	89367.3	18.28%	1.30%	0.68%	0.6
2065	1255285.0	81581.7	18.28%	1.19%	0.59%	0.5
2066	1255285.0	74484.4	18.28%	1.08%	0.51%	0.4
2067	1255285.0	67954.3	18.28%	0.99%	0.45%	0.4
2068	1255285.0	61940.4	18.28%	0.90%	0.39%	0.3
2069	1255285.0	56387.6	18.28%	0.82%	0.34%	0.3
2070	1255285.0	51332.7	18.28%	0.75%	0.29%	0.2
2071	1255285.0	46738.3	18.28%	0.68%	0.25%	0.2
2072	1255285.0	42553.2	18.28%	0.62%	0.22%	0.2
2073	1255285.0	38737.7	18.28%	0.56%	0.19%	0.2
2074	1255285.0	35260.4	18.28%	0.51%	0.16%	0.1
2075	1255285.0	32095.1	18.28%	0.47%	0.13%	0.1
2076	1255285.0	29217.8	18.28%	0.43%	0.11%	0.1
2077	1255285.0	26602.8	18.28%	0.39%	0.09%	0.1
2078	1255285.0	24215.8	18.28%	0.35%	0.08%	0.1
2079	1255285.0	22033.1	18.28%	0.32%	0.06%	0.1
2080	1255285.0	20035.9	18.28%	0.29%	0.05%	0.0
2081	1255285.0	18206.6	18.28%	0.27%	0.04%	0.0
2082	1255285.0	16529.3	18.28%	0.24%	0.03%	0.0
2083	1255285.0	14989.9	18.28%	0.22%	0.03%	0.0
2084	1255285.0	13566.5	18.28%	0.20%	0.02%	0.0
2085	1255285.0	12252.1	18.28%	0.18%	0.02%	0.0
2086	1255285.0	11041.5	18.28%	0.16%	0.02%	0.0
2087	1255285.0	9929.7	18.28%	0.14%	0.01%	0.0
2088	1255285.0	8911.5	18.28%	0.13%	0.01%	0.0
2089	1255285.0	7981.4	18.28%	0.12%	0.01%	0.0
2090	1255285.0	7134.2	18.28%	0.10%	0.01%	0.0
2091	1255285.0	6364.3	18.28%	0.09%	0.01%	0.0
2092	1255285.0	5666.5	18.28%	0.08%	0.01%	0.0
2093	1255285.0	5035.3	18.28%	0.07%	0.01%	0.0
2094	1255285.0	4465.5	18.28%	0.07%	0.00%	0.0
2095	1255285.0	3951.9	18.28%	0.06%	0.00%	0.0
2096	1255285.0	3489.5	18.28%	0.05%	0.00%	0.0
2097	1255285.0	2997.8	18.28%	0.04%	0.00%	0.0
2098	1255285.0	2550.1	18.28%	0.04%	0.00%	0.0
2099	1255285.0	2144.9	18.28%	0.03%	0.00%	0.0
2100	1255285.0	1780.7	18.28%	0.03%	0.00%	0.0
2101	1255285.0	1456.1	18.28%	0.02%	0.00%	0.0
2102	1255285.0	1169.9	18.28%	0.02%	0.00%	0.0
2103	1255285.0	920.7	18.28%	0.01%	0.00%	0.0
2104	1255285.0	706.8	18.28%	0.01%	0.00%	0.0