THE SYSTEM DYNAMI' 3 MODEL FOR POLICY
ANALYSIS OF THE FOREST INDUSTRY SYSTEM

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## ABSTRACT

By means of the system dynamics theory and approach, A system
dynamics model of the forest industry system for certain area is
set up,and the future developing tendency of the forest industry
system,under the conditions of various developing strategies and
policies,is discussed quantitatively using the computer simulati-
on based on the model.This model can provide scientific basis for
making a long-term programme for the developing of the forest
industry system.

## 1. FOREWORD

The forest industry is an important component of the national
economy and plays a specific role in the development of the nati-
onal economy.Since the founding of our new China, our country's
forest industry has achieved a lot in comprehensive exploitation
and utilization,and made a great contribution in national constr-
uction.However,the guiding ideology of management and utilization
of forest industry, for a period of time,has some deviation,the
forest exploitation and timber production has been emphasised;the
reforestation and comprehensive utilization have been ignored.As
a result the area of mature forest lands and exploitable resources
have reduced repidly,and the proportion of the amounts of forest
exploitation and reforestation is greatly imbalance.If the situa-
tion remains,it is impossible to achieve the goal of sustained-
yield utilization of the forest resources.

The existing of the above problems influences,directly,the pre-
sent production of forest industry and the forest resources for
susrained-yield utilization.Meanwhile, the repid reduction of the
forest resources also destroys the ecologic balance in some places.
So we should think about the problem that how we can,in practice,
produce more timber products,so as to give a full play of the
forest fuction in adjusting and improving ecologic envircnment
for public welfare,as well as meet the needs of our country's co-
nstruction in timber and forest products,under the condition of
keeping an everlasting resources for utilization and in view of
the above cases and the characteristics of the forest production.
This is a crucial problem that must be considered in the strategic
studies and policy analyses for the future development of the fo-
rest industry system.

## 2. THE BASIC STRUCTURE OF THE MODEL OF THE FOREST INDUSTRY SYSTEM

The model of the forest industry system consists of three subm-
odels:the analysis of forest resources growth and decline,capital
construction and fund management.The submodel of the analysis of
forest resources growth and decline can be further divided into
three parts, reforestation,forest resources and timber production.
The submodel of the capital construction embodies the comprehensi-
ve utilization of slash material,timber processing and fund for
the capital construction.The last submodel is composed of funds a-
ccounting,forwarding profits to the state,state investments and
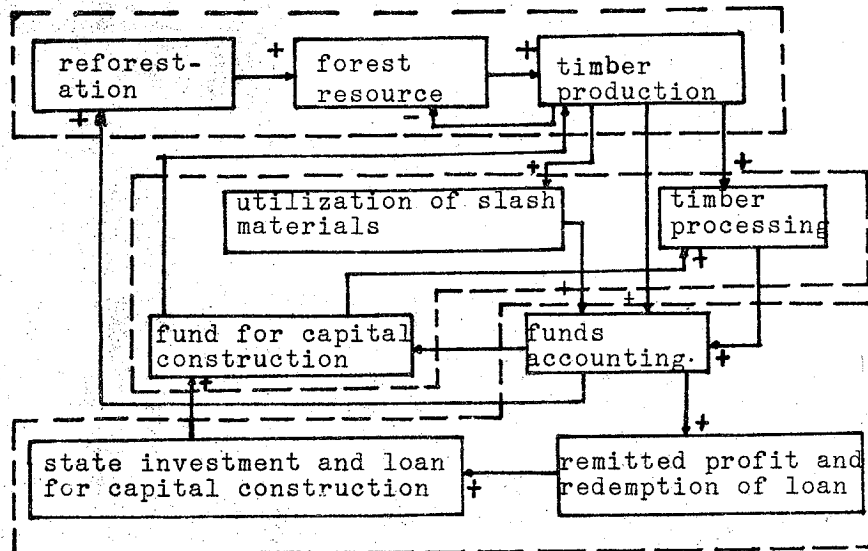loans.The relation between them is shown in figure 1.



Figure 1 Basic structure of the model.

In the model,the reasons for that the demands for timber from
the other trades are not considered are:
1) The forest resources in our country is extremely lacking,so
the supply of timber products will be far from satisfying the de-
mand of our country in a long period.
2) The system described by this model is a subsystem of provid-
ing timber products for the whole country.Under the extremely co-
ntradiction of supply and demand,the model can not simply produce
in accordance with the amount of need.However it tries to produce
as much products as possible,while ensuring a forest resources for
sustained-yield utilization.This is one of the significant chara-
cteristic of the forest industry system.

By the analysis given above, we can see the resource-restricting
factor is most important.

From the perspective of the system dynamic approach,the forest
industry system shown in figure 1 is a dynamic feedback system
which has the characteristic of non-linearity and multi-loops.The

external characteristic of the performance of this system is det-
ermined by a major loop.In this system,the loop composed of four
parts which are in the sequence of reforestation--forest resource
--timber production--funds accouting--reforestation,is a positive
loop.This positive loop represents the procedure of the utilizat-
ion and reproduction of the forest resources.When the loop plays
the major role in the system(i.e when there is an appropriate pr-
oportion between cut and increment),the forest resources will te-
nd to increase.Specifically,when the fund for reforestation grows,
the newly-reforested land will expand and the level of forest-te-
nding treatments will rise.So the forest resources will increase
after a period of delay time.In turn,the increasing of the forest
resources will lead to the growth of timber production,so that
the more forest fund and the more profits can be expected,and fi-
nally the fund for reforestation and forest management will furt-
her increase.The above circling procedure is a fine circle of co-
ntinously extended reproduction in the forest industry system.The
loop composed of two parts,forest resources and timber production,
in figure 1 is a negative feedback loop.This negative loop illus-
trates the interacting relation of the two parts.When this loop ac-
ts as the major loop,it will restrict the scale of forest produc-
tion within the system,that is,when the rate of the timber produ-
ction is higher than the growing rate of forest resources,the
forest resources will show a tendency of decreaseing.Although the
more fund for reforestation,achieved from timber production,can
speed up the rate of reforestation for a time,the cut too much
greater than forest increment can also exhaust the exploitable
forest resources and cause the vicious circle in forest industry
production,because the forest production circle is quite long(ge-
nerally speaking,70--80 years from planting to felling under the
present condition of management and production).The delay time
from planting to felling will have significant influence on fores-
t production.

   In figure 1,there are another three positive feedback loops,wh-
ich consist of,separately,(1) funds accounting--fund for capital
construction--timber processing--funds accounting;(2) funds accou-
nting--fund for capital construction--timber production--funds
accounting;(3) funds accounting--fund for capital construction--
utilization of slash materials--funds accounting.The three posit-
ive feedback loops illustrate the expanded reproduction procedure
of the processing industry and logging industry.In this model the
development of every industry discussed above has connection with
investment and the effects of the investment.

3. THE MODEL OF FOREST INDUSTRY SYSTEM

   The system dynamics model of the forest industry system embodies
more than 500 variables,the basic causal relations among the major
variables in the system are shown in figure 2.Because of the lim-
itation of space,we have to focus on the details only about the
submodel for the analysis of the growth-and-decline of forest
resources.

Figure 2 The Causal Relationships of the Major Variables
(Join the two figure 2 together.)

forest fund
for capital
construction

state investment
for capital
construction

production
capacity for
logging

production
capacity of
every forest
product
industry

timber outpu
for final
accounting

+ newly increased
fixed assets for
forest management

capital
construction
investment
for logging

capital
construction
investment
for forest
product
industry

investmental
effect

output of
saw-lumber

output of
plywood

total revenue
from sales

output of
fibre board

increasing
rate of
fixed assets

renewly and
renovation
fund for
capital
construction

withdrawn fund
for renewal
and renovation

total
cost

output of
shaving boar

net value of
fixed assets

total
taxes

withdrawn
forest fund

output of
other produc

renewal and
renovation
fund from
depreciation

profit for
returning
loan

profit from
product sales

forwarding
profits to
the state

original cost
of fixed assets

the loan

newly increased fixed
assets of the culture-
education-health and
service trades in the
forest industry

newly increased
fixed assets of
the other industries
in forest industry

retained
fund

the total
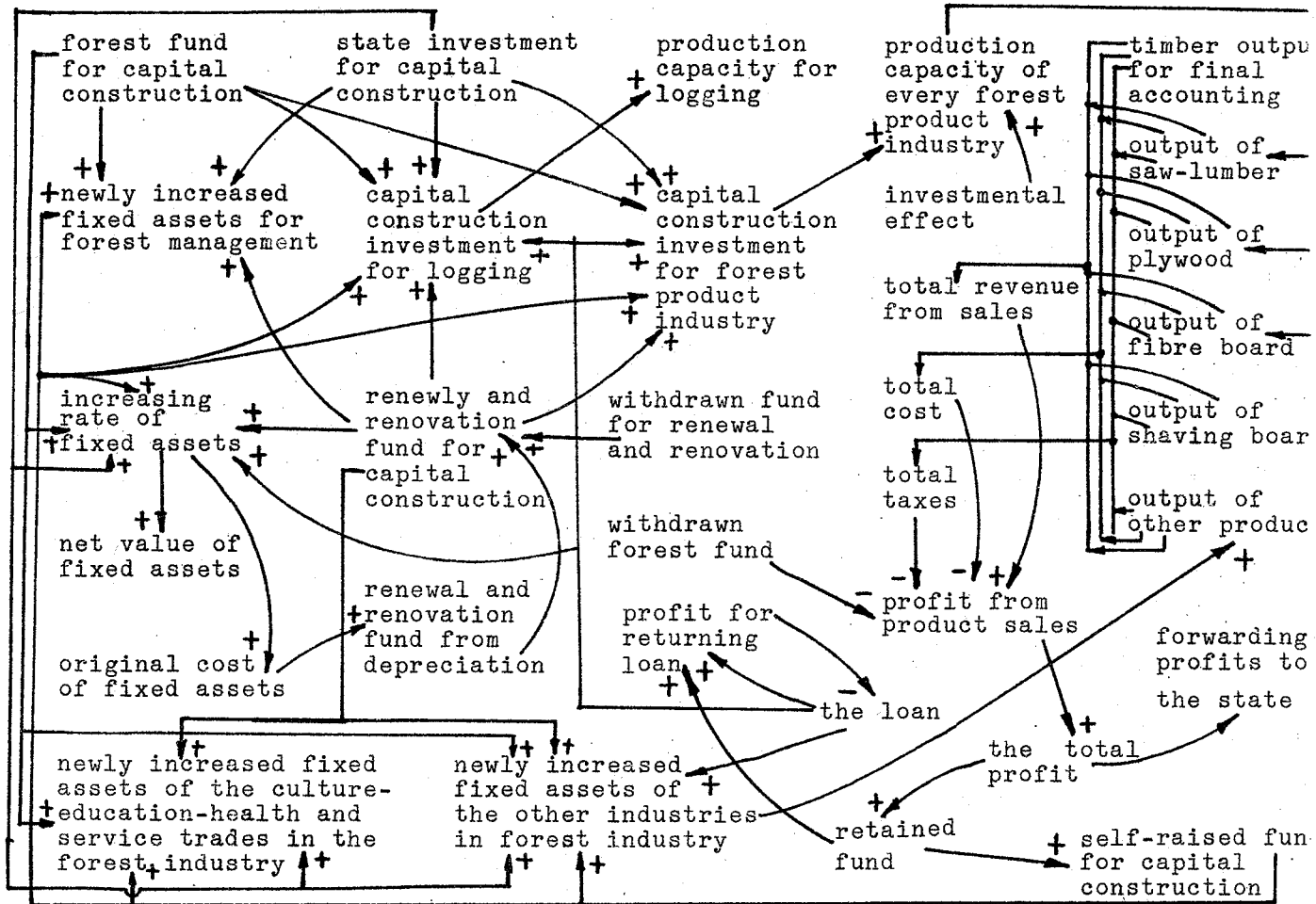profit

self-raised fun
for capital
construction

Figure 2 The Causal Relationships of the Major Variables
(The Continuation of the Figure 2)

3.1 The Submodel of the Growth-and-Decline of Forest Resources

   The submodel of the growth-and-decline forest resources mainly
describes the proceeding of the utilization and the reproduction
of forest resources.The part of the forest resources utilization
includes two sections:the rational use(the normal felling)and the
irrational use(reckless felling and the loss caused by others),
while the part of forest resources reproduction is mainly achiev-
ed through the reforestation and the rising of the forest manage-
ment level.

A. The Section of the Forest Resources

   In this part of the model,the variables describing the quantity
of the forest resources are the area of the unclosed forest land,
and the areas and the growing stocks of the young growth land,the
middle-aged forest land,mature forest land and the secondary for-
est land.The relations among all sorts of forests may change in
the following way:
   1) The reduction of non-stocked land caused by reforestation
      increases the area of unclosed forest land;
   2) The reduction of unclosed forest land caused by closing
      increases the area of the young growth land;
   3) The decreasing of young growth caused by growing increases
      the area of middle- aged forest;
   4) The decreasing of middle-aged forest caused by growing
      increases the mature forest land;
   5) The decreasing of middle-aged forest land caused by careless
      tending felling increases the secondary forest land;
   6) The decreasing of the mature forest land caused by clear
      felling increases the non-stocked land;
   7) The decreasing of the mature forest land caused by selection
      felling increases the middle-aged forest land;
   8) The decreasing of the mature forest land caused by nonstand-
      ard selection felling and reckless cutting increases the
      secondary forest land;
   9) The decreasing of the secondary forest land caused by impro-
      ving increases both the young growth land and the unclosed
      forest land;
   10)As a result of fire,disease and insectpest and so on,the loss
      of the unclosed forest land,young growth,middle-aged forest
      and the mature forest increase the area of non-stocked land.
The utilization and reproduction of the forest resources are des-
crided by the changing relations of all the various forest land.

   Here,taking the calculation of the area of the mature forest
land as a example,we shall represent the calculating procedure of
the quantity of the forest resources.The formulations of calcula-
ting the mature forest land are:
   AL5.K=AL5.J+DT*(AR6.JK-AR8.JK-AR9.JK-AR10.JK-ARS5.JK-AR11.JK-
      -AR13.JK)                                                3-1, L
   where
   AL5-- mature forest land                           (hectare)

AR6-- growing rate from middle-aged to mature(hectare/year)
AR8-- selection felling rate (hectare/year)
AR9-- clrar felling rate (hectare/year)
AR10--fire damage rate (hectare/year)
AR11--reckless felling rate (hectare/year)
AR13--nonstandard selection felling rate (hectare/year)
ARS5--other damages rate (hectare/year)
The following is the formulation of calculating mature forest
growing stock.
  AA21.K=AL5.K*AC23.K                              3-2,A
where
  AA21-- mature forest growing stock    (cubic metre)
  AC23-- average hectare growing stock  (cubic metre/hectare)
In this formulation,the variable AC23 increases and tends to be
saturated,as the cost of forest-tending and the level of forest
tending grow.

B. The Section of Timber Production

  The timber production section describes the possible output of
timber production under the condition of certain forest resources.
The principle of the controlling of the output is that cut must
be lower than increment.

  When the total growing stock of forest resources has been calcu-
lated,the increment of the forest resources can be calculated
with the following formulation:
  AA23.K=GT1.K*GTC1.K                              3-3,A
where
  AA23--total increment of the forest resources(cubic metre/year)
  GT1 --total growing stock                      (cubic metre)
  GTC1--integrated increment rate                (percentage/year)
The integrated increment rate in the formulation is a variable.As
the forest-tending level grows,its value will increase and wil‾
be represented by a table function in the model.

  In order to define the actual felling quantity in this model,we
should first calculate the exploitable growing stock of final fe-
lling according to the principle that"the cut is equal to the inc-
rement".The exploitable growing srock of final felling is the ma-
ximal felling amount of certain forest resources,and it can be ca-
lculated in the following formulation:
  AA24.K=AA23.K*AC25-A23.K                         3-4,A
where
  AA24--exploitable growing stock of final felling
                                       (cubic metre/year)
  AC25--proportion of the timber forest (percentage)
In practic,in order to realize the goal of sustained-yield utili-
zation of certain forest resources,the felling quantity should be
further controlled,especially,when the forest resources have been
overcut.The actual final felling growing stock must be lower than
the exploitable growing stock of final felling.

  In the model,the function of the controlling cut is realized th-

rough the policy variable.The policy variable is a function of time, its value is between one and zero.The actual final felling growing stock is equal to the product of exploitable growing stock of final felling and the policy variable,that is

$$AA28.K=AA24.K*AA27.K \qquad\qquad 3-5,A$$

where
  AA28--actual final felling growing stock    (cubic metre/year)
  AA27--policy variable                        (cubic metre/year)
The AA27 in the equation is a table function as follows:

$$AA27.K=TABHL(TAA27,TIME.K,1980,2030,10) \qquad 3-6,A$$
$$TAA27=1/0.85/0.8/0.78/0.75/0.7 \qquad\qquad 3-7,T$$

When the AA27 is equal to one,the actual final felling growing stock will be equal to the exploitable growing stock of final felling,but it will not.The reason that the AA27 will take smaller and smaller is that the proportion of young growth and middle-aged forest land get larger and larger in the forest industry system discussed.If we produce so timber according to the principle that cut must approximate increment,we can not realize the goal of sustained-yield utilization.The AA27 is an important variable controlling the quantity of the timber production,its value greatly influences the forest industry production.

The timber products,in this model,is composed of two parts:the final felling output and the amount of timber produced by thinning.The final felling output is mainly limited by the both of the resources and the capacity of logging.

C. The Section of Reforestation

. In the real world,various factors influence the reforestation. Here we only consider the funds for the reforestation,the cost, the survival percentage and the non-stocked land.In the respect of the organizational forms,we only consider three forms:the state-operated forest farm,the collective and private reforesting and the natual regeneration.

3.2 The Submodel of Fund Management

In this submodel,the factors mainly considered are the following:the sale volumes of logs,saw-lumber,plywood,shaving-board and other wood products;and the variables such as sales revenues, production costs,taxes,the total profits and some other special-purpose funds.Here we assume that the demand for logs and other wood products in the society is far larger than the outputs respectively,this means that the sale volume is equal to the output; and the output of the main products is basically determined by the production capacity applied in reality,but restricted by the log output and the amount of slash.The raw materials of plywood and saw-lumber,for example,are logs,so the output of these two sorts of products must be restricted by the logs output.

The submodel,through the calculation of the sales revenues,production costs and the taxes of various products,calculates the possible profits and possible funds for special purposes and exp-

anded reproduction in the forest industry for each year.Here the
profits are divided into three parts:the part of the redemption
of loan,the part turned over to state and the part self-retained.
The capital construction fund from the self-retained part is the
main source of the self-raised capital construction fund;the for-
est fund drawn from log sales is divided into remitted forest fund
and the self-retained forest fund,the self-retained forest fund
is the main sourcs of the forest planting fund and the fund of.
capital construction for planting;the fund drawn for the renewal
and renovation is also divided into two parts:the part for trans-
formation and energy and the part for capital construction.Note
that the latter is used,as capital construction,in the forest in-
dustry system.The average price,cost and the tax per unit for
each sort of the products in the model are function of time,they
are represented with table functions and their specific values
will have significant influences on the fund for expanded reprod-
uction in the forest industry system.

3.3 The Submodel of Capital Construction

This submodel mainly considers the funds provided for capital
construction,the proportion of the invesments of all kinds of tr-
ades,the scales of newly-added fixed assets of some trades,the
production capacities,the scale of the fixed assets of the forest
industry system and so on.The source of the capital construction
fund consists of the state investment,self-raised fund,the renew-
al and renovation fund for capital construction,the forest fund
for the capital construction and the loan.Among them,the renewal
and renovation fund,the forest fund and the self-raised fund for
capital construction are produced inside the system,while the st-
ate investment and the loan are input variables.In this model the
loan is mainly used in the timber production,forest products and
other industries,the state investment is approximately the same
as the remitted profit of the forest industry system.with the po-
licy analysis the different effects on the development of the fo-
rest industry system,caused by different values of investment,are
tested.Note that the investment used in the model before 1983 is
the actual values,while the investment after 1984 is an estimated
values.Here we divide the forest industry system represented by
our model into five major trades:reforestation, logging and tran-
sportation,timber processing,and the other industries as well as
the culture-education-health and service.And the timber processin-
g can be further divided into saw-lumber production,plywood produ-
ction,fibre board production,shaving board production and comprehen-
sive utilization production.

This submodel focus on the distribution of various capital con-
struction funds and the formation,depreciation and diminution of
the fixed assets.Based on the above discussion,under the conditi-
on of the limited funds for capital construction the submodel de-
scribes the effects on the development of the forest industry pr-
oduction and the profit that can be realized.These effects are ca-
used by different investing plan,different period of the capital
construction and the different investment efficiency.At the same

time,the model also can be used to discuss the proper approach of
realizing the goal of the profit that is to be achieved by the
forest industry system by the end of this century,as well as the
departments and trades that should be given the priority to the
developing.

## 4. POLICY ANALYSIS BASED ON THE SYSTEM DYNAMICS MODEL

This system dynamics model of the forest industry system is for-
med organically with three submodels discussed above.In the study
we can use this model to carry on simulation for various policies
and developing trategies.Having limited space,we can only represe-
ent some of the typical simulations of policy analysis.

### 4.1 Policy Analysis for Utilization and Management of
the Forest Resources

In this section,in terms of the simulations of the system dynam-
ics model,two different policies that may infleunce the tendency
of growth-and-decline of forest resources are analysed.The polici-
es used in the simulations are:
1) Keeping,basically,the present forest-tending level,and havi-
ng the cut approximately equal to the increment;
2) Keeping on rising the forest-tending level,and make the cut
lower than the increment.
When the first policy is followed in the simulation of the forest
industry system, the condition for the model simulation is,basica-
lly,same as that for the basic model simulation.In this case,the
tendency of the changing of the forest resources are that the yo-
ung growth land keeps on increasing,before 2014,and then tends to
decline;that the middle-aged forest land increases throughout;th-
at the mature forest land declines to the lowest point of 590,000
hectare in2052,and then tends to grows; that the total timber pro-
duction tends to decline until the lowest point of 10,880,000 cu-
bic metre,and then begins to going up after 2010.From the results
of the simulations,we can see that if the total output of timber
production maintains under 11,000,000 cubic metres,the goal of
getting sustained-yield utilization can be achieved.However,it is
impossible in reality,because in the mature forests there are nat-
ural protective forests,seed stands and other intouchable resour-
ces.(e.g in 1983,the natural protective forests and the seed sta-
nds are 440,000 hectare,and they are intended to grow)

When the second policy is used in the simulation,the condition
for the model simulation will change.The changings are mainly
following:
1) Increase the cost of reforestation and forest-tending;
2) By means of rising the tending level of the forest resources,
increase the growing stock per hectare,the integrared increm-
ent rate and the increment of forests,and shorten the maturi-
ty of forest;
3) According to the principle that the cut must be lower than
the increment,control the felling amount.
In these cases,the changing tendencies of the forest are that (1)

the young growth forest land tends to going up before 2008 and th-
en begins to decline,the maximal value is 3,040,000 hectares;(2)
the middle-aged forest land grows throughout and the maximal val-
ue is 5,550,000 hectares;(3) the mature forest land,before 2032,
tends to decline and the minimal value is 700,000 hectares,then
going up;total increment,thinning outturn and the growing stock
of final felling are generally rising;total output of the timber
is going up before 2028,then is stably remaining at a value of
20,000,000cubi-metre.From the results of the simulation,it is cle-
ar that the second policy is better than the first one,because it
can not only realize the goal of getting a sustained-yield forest
resources for utilization,but also raise the output of the timber
production.For the purpose of comparison,the results of the two s-
imulations are drawn in figure 3.The non-stocked land is also dra-
wn in the figure,just as the description above,the time for the
non-stocked land(2) diminishing to zero is about 20 years later
than that for the non-stocked land(1),it results from lack of
fund caused by the changing of management methods from the extens-
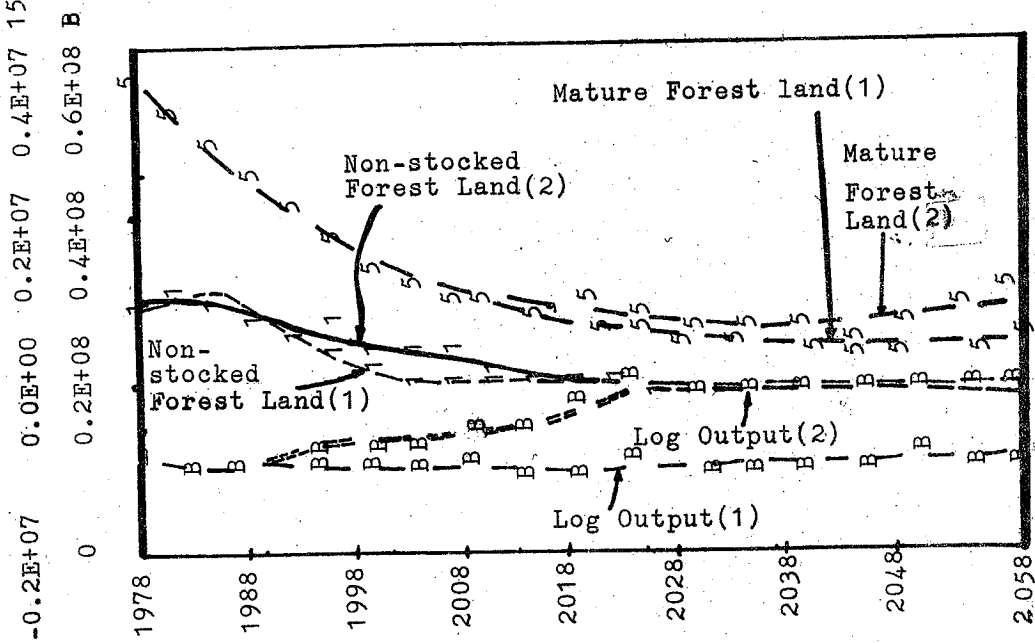ive to the intensive.



Figure 3: The results of the two simulation
((1) and (2),respectively,represent the results of
the first and the second policy.)

## 4.2 Investment Policy Analysis for the Capital Construction

From the above analysis,we can see that the timber production
won't grow much in the near future because of the limitation of
the forest resources,so,in order to realize the goal of providing

more wood products for the country,the forest industry system sho-
uld devote greater efforts to developing the forest products trade
,especially pay more attention to the wood comprehensive utiliza-
tion industry.Since the industrial basis for wood comprehensive
utilization is rather poor,the forest industry system should make
more efforts in the capital construction of this industry.

   Having limited fund for the capital construction of the forest
industry,we should give consideration for the development of other
trades,while giving priority to the development of wood comprehen-
sive utilization industry.Therefore,we,in this section,mainly an-
alyse the possible development tendency of wood comprehensive ut-
ilization under the condition that the state investment for the
capital construction,before 2000,is basically equal to the profit
turned over to state by the forest industry system,and is maintai-
ning 250 million yuan after 2000.The tendency of changing the pr-
oduction capacity of fibreboard and shaving board is drawn in fi-
gure 4.If the preceding policy is adopted,the production capacity
of fibreboard and shaving board will grow repidly before 2000,and
then it will grow slowly and tend to stability at last.In the case
that the utilization ratio of the slash and scrap materials is
lower,increasing the amount of investment can raise its producti-
on capacity quickly,and can also raise the capacity of comprehen-
sive utilization;and because of the restriction of the total amo-
unt of the slash and scrap materials,the investment will be dimi-
nished gradually later to slow the developing speed.It has been
calculated that the production capacity of fibreboard and shaving
board will reach,respectively,630,000 cubic metres and 340,000
tons in 2000;while the investment for shaving board will amount
cumulatively to 197 million yuan.Because of the limitation of the
capital construction fund,their production capacity grows slowly
before 1990.

4.3 The Policy Analysis for the Wood Price

   The present price structure for the wood products is quite unr-
easonable.The log price is too low and the cost of forest-planti-
ng is not included in the price.As a result,there is a obvious
gap between the price and the value,which influences the developm-
ent of forest industry seriously.For this reason,the forest depar-
tment has put forward a proposal that the log price should be ri-
sen in our country.(The average price of each cubic metre should
raise 37 yuan.)

   In this section,our simulation analyse the stimulating effect
on the forest industry production,if the price of each cubic met-
re log raise 20 yuan from 1985 (10 yuan added to the forest fund,
10 yuan for the cost value of forest).(In the simulation,we also
adapt the price,cost and tax of the saw-lumber and the plywood.)
The stimulating effects are mainly following:
   1) Rising the reforestation expense will speed up the reforest-
      ation rate;comparing with the system in section 4.1,the work
of reforestation on the non-stocked can be done 28 years earlier.
   2) Under the condition that the minimal value of the mature

forest land rises 4 percent,the output of log will rise 3 percent.
  3) Increasing the capital construction fund can speed up the
     development of the wood comprehensive utilization industry,
     and to some extent,raise the production capacity,at different
     level,of all kinds of wood products.
  4) The total profit increases strikingly,comparing the simulat-
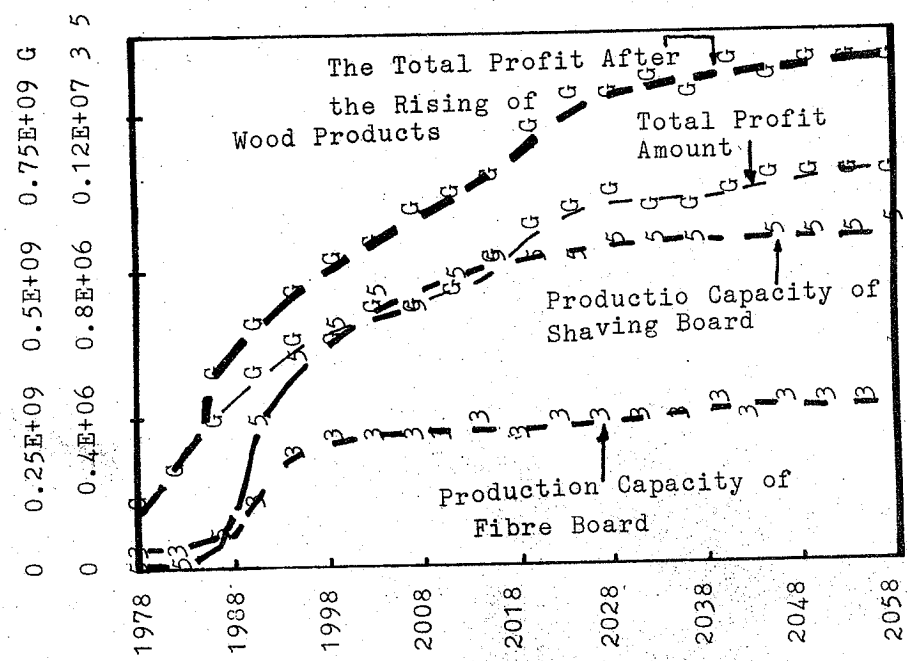     ion result in figure 4.



Figure 4:Partial results of the simulation of the
         submodels of capital construction and fund
         management

## 5. CONCLUTION

   By analysing the simulation results,we can draw the following
general conclution:1) The forest resources is the most important
restricting factor of the whole forest industry production,and
the most important approach to increase the forest resources is
to change the management and administration from the extensive to
the intensive.However,under the condition that the forest manage-
ment fund chiefly comes from the forest fund,as the proportion of
drawing the forest fund is relatively small and the log output is
not high,the forest management fund is consequently less and can
not meet the needs of accelerating the speed of the reforestation
and of rising the level of forest-tending(e.g according to the de-
veloping project,by 2000 year,theincrement rate of the forest sho-
uld be promoted by 100%,but in this model it only rises by 40%);
2) The present wood sale price is too low and in turn the profit
of the forest industry system is also very low,which can not meet

the demand of the expaned reproduction of the forest industry sy-
stem.Hence,the rising of log price by about 20 yuan per cubic met-
re will have certain facilitating effect on the fine-circle of pro-
duction of the forest industry system,anyhow,the problem can not
be solved completely;3) The capital construction investment is to-
o low before 2000,it can not meet the needs of the forest indust-
ry development significantly.(e.g The output of the shaving board
should be 1.3 million cubic metres,required by the project,in
2000,but the number given by our model is only 630 thousand cubic
metres.) So the forest industry should be given more supports by
the government.

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