AGRICULTURAL RESEARCH ORGANIZATION

INSTITUTE OF FIELD & GARDEN CROPS ☆ INSTITUTE OF ANIMAL SCIENCE

MIGDA SYSTEM 1 (MIGS 1): A MODEL FOR STUDYING MANAGEMENT SYSTEMS OF AN INTEGRATED SHEEP-WHEAT FARM IN THE SEMI-ARID ZONE OF ISRAEL

N. G. SELIGMAN, R. W. BENJAMIN and E. EYAL

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THE VOLCANI CENTER, BET DAGAN, ISRAEL
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Abstract

The computer simulation model presented in this publication describes a farm system that comprises wheat cultivation and pasture used for sheep husbandry. The wheat fields generally produce grain and straw, but under certain conditions they can be cut for hay or grazed. The sheep flock produces lambs for sale and hoggets for ewe replacement. Wool also provides income which, under existing price ratios, is minor compared with the income from lamb. The model calculates biological and economic parameters which can be used to determine the efficiency of different management manipulations under varying economic and environmental constraints.

The model was tested on a ley-farming system in the northern Negev of Israel and served to elucidate some of the factors that determine its profitability. The model and some of its output can also be used to develop management aids for farmer and extension use, particularly where integrated crop and livestock husbandry create complex management problems.

INTRODUCTION

It has been shown that integration of sheep husbandry with wheat farming in the semi-arid northern Negev of Israel should stabilize income and reduce dependence on government drought subsidies (13, 14). Nevertheless, the practice has not been accepted, for reasons that are not quite clear. The purely economic advantages are offset by the fact that non-integration is supported by drought compensation, but it has also been argued that the complexity of and year-round involvement in sheep-husbandry are too heavy a burden to offset the economic cost of non-integrated wheat farming. This argument would hold if the advantages of integration were slight, but would be difficult to support if the economic gain were clearly and substantially greater. It is clear that the integrated systems proposed in the past are not based on an optimum management strategy, nor have they been tested in a fully controlled situation. There is thus a case for investigating the margin for improving profitability and demonstrating its feasibility in the region. One of the purposes of the joint Israeli-Dutch research project* can be seen in this light: to determine the potential profitability of crop and animal production in the climatically uncertain semi-arid region. The physical part of the project is being conducted on an experiment farm (Migda) near the Gilat Regional Experiment Station. Part of the project is devoted to an analysis of the management options that can be defined for integrated systems. The model described in this report has been defined so as to facilitate this analysis.

1. Basic Structure of the Model

The model envisages one hectare that represents an integrated sheep - wheat farm. The wheat and pasture growth rates are entered as driving variables derived

* Actual and Potential Production of Semi-Arid Grasslands, Phase II (APPSAG II).

from field measurements or other crop and pasture models (5, 6). The sheep population dynamics, liveweight and fertility are calculated subject to various management constraints: the wheat can be grazed, harvested, or cut for hay, and the aftermath grazed or baled as straw; the hay or straw can be stacked or sold. All economic inputs and outputs are entered into a current balance which is summarized once a year.

The dynamic sector of the model is divided into the following sections: Timing, Accounting, Sheep flock dynamics, Sheep liveweight and fertility, Feed supplementation, Supplementary roughage availability (hay, straw), Grazing management, Paddock allocation, and Pasture and wheat growth.

The management options can be selected by parameter changes: some are built into the model, others need to be defined as combinations of parameters. The data on which the model is based are entered as a set of parameters and function tables. The model can be initiated at any stage of the production year so as to make use of recently available information on the state of the system.

2. Model Description

The listing of the model is given in Appendix I. In the following sections, the numbers in the left-hand margin of the page refer to the line number where a variable being discussed is defined in the listing.

368/419 2.1. Timing (sections 6,7,8)

The model is based on time steps of one week; week 1 starting on October 1, the traditional beginning of the "agricultural year" in Israel. This is the time of the year for accounting, but the actual starting week can be set at any week in the year.

The system variable TIME counts the weeks, which can con-
371 tinue over a number of years. YTIME is the week of the year
starting on October 1. The beginning of the accounting year is
372, 373 flagged when NWYR = 1, which occurs when YTIME = 0. RTIME is the
374 week of the calendar year; and MONTH is the month of the calendar
year. All events that need to be flagged (joining, plowing, harvesting, etc.) are defined in RTIME (calendar weeks).

The course of the growing season is monitored separately as
388, 418 ASMWK, which counts the number of weeks from germination (GERM)
419 and from the end of the growing season (EGS). During the growing

season a growth rate factor (SM) which represents the integrated
effect of all climatic variables, is greater than zero. The table
141/5 of SM values is calculated independently of the model (see
Appendix IV) and is based on the actual undisturbed growth curve measured in the field or calculated by means of a canopy growth model. SM is a factor between 0 and 1 based on a calculation of actual growth rates and a potential value based on observations in the region; it is calculated on the basis of exponential growth until the canopy closes (at about 1900 kg dry matter per hectare [DM/ha]). After canopy closure, potential growth rate is taken as constant at about 200 kg DM/ha/d. If actual growth rates exceed the potential rates used, SM can attain values above 1.

Flag days are signaled as 1 on the day of the event, 0 other-
wise. Most flag days are calculated with a standard function MACRO
92/4, 398/405 MACT which inputs the week (in YTIME) in which the event takes
place, and outputs 0 or 1. The calendar weeks are converted to
97/9, 349/359 YTIME by another MACRO CT which is activated in the initial sec-
tion of the model. Once an event has taken place, its occurrence
is maintained on record until the record becomes redundant. This
102/5 is done with MACRO CDX, which also records the week in YTIME that
the event took place. The following events are not preset, but
411/5 are calculated by the program; weaning date, sale date of weaners,
germination date, and end of growing season date.

425/503 2.2. <u>Accounting</u> (section 9)

Tha accounting system is highly simplified so as to give an
indication of the main costs and benefits of the system being
tested without becoming involved in complexities such as money
flows, credits, and inflation effects. It assumes constant prices,
an initial balance, a constant updating of income, end-of-the-year
entry of costs, and separate interest rates for positive and nega-
tive (overdraft) balances. These are maintained as an annual
428 balance (ANBAL).

432/4 The gross income (GRINC) accumulates income from sale of lambs,
weaners, ewes, wool, wheat grain, excess straw and hay. The grain
437 harvest is the average for all fields that have not been grazed.
750, 757/8 Wheat yields of grazed fields are regarded as zero if grazing

267/8, 282 took place later than a threshold date (NOGEF). The details of the
472 procedure are given in the section on wheat and pasture growth.
438 Grain is sold and used after harvest. Wool yield is taken from
ewes only.

440 The number of weaners sold is that above the number needed for
441/3, 129/131 ewe replacement. The price for lamb and mutton can vary with the
135 time of year and with the lamb and ewe body condition.

444/468 Price of hay and straw sold after harvest (HARV1) depends on
467/8 the year; it goes up in bad years and down in good years (HPINC,
SPINC). Limits are set on these fluctuations, so that price will
455, 458 not go far below half or much above twice the average price. A
poor year is one when the primary production of the least grazed
453/7 (or ungrazed) wheat field (PP4) is < 3 t/ha. A good year is one
when PP4 is > 6 t/ha.

474, 230 Lambs are sold at weaning unless raised as weaners (RAISW = 1).
Weaners that are not being retained for ewe replacement are sold
477/484, 705 as soon as their liveweight increase (WLWCH) drops below a minimum
233 rate (MINWGR), as soon as they reach sale weight (SWW), or when it
355, 175 is close to the plowing date (PTIM).

488/502 The costs of the operation are calculated at the end of the
year (October 1st = NWYR). In the program they are in fact calcu-
lated in the last week of the current year, which is when plowing
492 (or discing) of the wheat field is set to take place. The costs
reflect the current year's expenses for maintenance of pasture
(CPAST); wheat cultivation (CCULTW); wheat harvest (CHARW); sup-
plementary feeding (CSUPP); preparation and baling of straw and
hay (CHARS, CHARH); miscellaneous sheep expenses such as veteri-
194 nary costs (FXVPE) which are dependent on the breed (BREEDF);
196/7 fecundity hormones (HORMT); and cost of labor per ewe (CLPE). Also
191 included is the interest on the value of the sheep (DEPOSR *
INEWE). The cost of ram maintenance is not taken into account
separately.

193 The cost of the pasture includes a fixed cost (FXPC), fertil-
izer cost, and pasture seed cost - to the extent that seed was
273 used (IGVP).

The wheat harvest cost is made up of a fixed cost based on
194 the area harvested (FHC) and on a variable cost dependent on the
194 amount of grain harvested (VHC). The cost of wheat cultivation
until harvest (discing and sowing, fertilizers, seed, etc.) is
194 entered as a parameter (CCULTW).

The supplementary feed costs account for two types, expensive concentrate feed (CONCF) and a cheap roughage - in this case cotton gin waste (COTW); the latter item represents feeds based on locally available agricultural wastes.

The hay and straw costs include raking and baling only. The
781/2 amounts of straw (BALSC) and hay (BALHC) are calculated elsewhere.

508/542 2.3. <u>Sheep flock dynamics</u> (section 10)

Only three classes of sheep are monitored: ewes, lambs and wean-
ers. Rams are not accounted for separately but can be regarded as
ewes for feed balance and costing purposes. In this case it would
224 be necessary to adjust the lambing rate (BREEDF) accordingly. As
the ram : ewe ratio is around 1 : 30, the effect of ignoring the
rams completely is probably insignificant, if the practice is
consistent among runs. Hoggets are classified as weaners until
the end of the current season, and then they are re-classified
as ewes.

509 The number of ewes (NEWES) is set initially (INEWE). The
410 ewes are culled one week after weaning (CTIM) and replacement
hoggets are added one week before the end of the current season
230 (PLOW). Ewe mortality (EMORT) is set as a parameter but mortality
510 occurs throughout the year. The dead ewes are registered in DEWES.

511/6 The number of lambs born is determined by one lambing week
398, 349, 176, 174 (LAM), which occurs 21 weeks after a pre-set breeding week
(JWEEK). The number of lambs born depends eventually on ewe condi-
514, 513 tion at joining and at lambing (ECON), on the breed characteris-
515, 516 tics (BREEDF), on hormone treatment (HORM), and on lamb survival
(LSURV) soon after birth.

514 THE REDUCTION-FACTOR-DEPENDENT EWE-CONDITION (EWCON) AND THE LAMBING SURVIVAL FUNCTION (LAMRT)

134, 136/8

FUNCTION EWCONB		FUNCTION LAMRT	
EWCON	ECON	BRDFR	LSURV
0	0	0	1
1	0	0.5	1
2.5	1	0.8	0.98
4.0	1	1.0	0.95
5.0	0.5	1.5	0.9
		2.0	0.85
		3.0	0.7

At lambing (LAM = 1), EWCON is reduced by 0.2 to calculate actual lambing rate.

552 EWCON is defined as a linear function of ewe weight (WEWE)
225 between ZERO, which is the mean breed weight at zero condition,
225 and the maximum breed weight (MXBRW). The scale runs from 1 to 5
and can be measured subjectively by palpating the sheep spine in
the lumbar region and estimating the fat cover of the vertebrae
513 (4). The variable, BRDFR, monitors the effect of ewe-condition
224 and hormone treatment on breed fecundity (BREEDF) at joining
398, 174, 164 (JOIN). It is set to zero at weaning (WEAN = 1). The hormone
515 treatment (HORMT) is ineffective if ewe condition at joining is
224 < 2. If hormones are not used, HORMT = 1; if they are used,
HORMT > 1, the exact value depending on the breed and other fac-
tors, and a reasonable estimate has yet to be determined. On
522/535 weaning (WEAN = 1), all lambs are either sold or transferred to
511 the weaner category. Lamb mortality after the first week and pre-
dation of lambs (and ewes) is not taken into account in the pre-
474 sent model. If the lambs are sold (SELLL), this is done at weaning
so that considerations for selling are included in the weaning
522, 230 routine. Lambs are sold if they are not raised as weaners (RAISW =
0).

518 Replacement of culled ewes is done at weaning (WEAN = 1) and
224, 230 covers both a culling rate (CULLR) and annual ewe-mortality
(EMORT).

522/535 Weaning depends on a number of factors and management criteria. These can be changed and, in principle, can be optimized. Lambs are weaned when any one of the following conditions is met:

525, 229 a) lambs are older than a minimum weaning age (THEW), an early
230 weaning option is set (EARLW = 1), and liveweight increase is < 200 g/d;

526, 552 b) lambs are more than 4 weeks old and ewe condition (EWCON) is
225 less than a threshold condition (ECWN);

527 c) the green season is over and only 300 kg dry pasture per hectare is left on the area available for grazing;

528, 227 d) the weight of lambs is above a maximum weaning weight (WLW);

528, 689 e) lambs are over 4 weeks old and the liveweight increase (LMWCH) is < 100 g/d;

713, 227 f) the age of the lambs (AGW) is above a preset age (FWAGE); or

530 g) it is 4 weeks before joining and lambs have not yet been weaned.

533/4 Lambs are sold when any one of the following criteria is met:

687 a) the liveweight of the lambs is > 50 kg;

350 b) the breeding season has started; or

689 c) the liveweight increase of the lambs is < 100 g/d and the weaners will not be raised (RAISW = 0).

540/1 The weaners include hoggets that will be raised for replace-
518 ment (REPL1) and those raised for fattening on pasture if that option is set (RAISW = 1). The number of weaners is reduced when
477/82 those to be fattened are sold (SELLW). All weaners are classified as ewes at the end of the current year at plowing time (PLOW = 1).

2.4. Sheep liveweight and fertility

548/551, 225 2.4.1. Ewe liveweight. Initial weight of ewe must be preset
554/8 (IWEW). The weight is changed weekly according to the energy balance (EWCH). After lambing, a reduction in ewe liveweight is recorded due to weight of the lamb and of the after-birth. A further correction is recorded at the end of the season, when the

weaners are moved into the ewe category. The ewe is an average one representing the mean for the flock. No attempt was made at this stage to place ewes in discrete classes.

554/9 The ewe liveweight change (EWCH) is calculated from the ewe
561 feed balance (EWFB), which is based on the digestible dry matter
574 intake from pasture (EWINT * DIGPE), from supplementary feed
569/70 (SUPPE), and the requirement for maintenance (DIGDME).

The digestible dry matter (DDM) requirement for ewes is proportional to its metabolic body weight ($WEWE^{0.75}$), and a parameter relating requirement to weight, KMNT (= 0.04 kg DDM/kg). If the ewes are grazing (DEFERR = 1), then maintenance requirements will increase as the pasture becomes increasingly sparse and the intake drops. The maintenance requirement for grazing can, in an extreme case, be doubled. If intake of green or dry pasture EGPI1 or EDPI1, respectively) is equal to the potential intakes of green or dry pasture (PGCXE or PDCXE, respectively), then there will be no increase in maintenance requirement.

From the feed balance (EWFB), allowance must be made for milk production. This is not defined explicitly, as the digestible dry matter requirement for lactation is calculated from the lamb
555 liveweight gain and maintenance requirement. The equation used is:

$$EWCH = EWFB * 0.55 - LER * 0.62 * (LMWCH/0.77 + KMNT * WLAM^{0.75})$$

where EWCH = mean ewe weight change (kg/sheep/d),

EWFB = ewe feed balance (kg DDM/sheep/d),

0.55 = conversion factor of DDM to ewe liveweight (1),

LER = lamb/ewe ratio,

0.62 = conversion factor of DDM (in milk) to lamb liveweight (9),

LMWCH = lamb weight change (kg/lamb/d),

0.77 = conversion factor of lamb liveweight change to DDM, and

229 KMNT = coefficient for calculation of DDM requirement per kg of lamb metabolic weight.

557 If EWCH is < 0, then fat reserves are being utilized, and the liveweight change is adjusted as follows:

EWCH = EWCH * 15.481 * 0.62/(20. * 0.8), where

15.481 = metabolic energy content of 1 kg DDM (MJ), and

20.*0.8 = metabolic energy of 1 kg sheep liveweight loss.

562/576, 562 Dry matter intake of the ewe from pasture (EWINT) is calcu-
lated separately for green pasture and dry pasture, and includes
563/4 pasture intake of the lamb. Green plant components are always pre-
ferred and dry plant components will be taken only if the green
fraction is less than potential dry matter intake for dry pasture.
566/7 Intake is limited by the maximum daily pasture intake of an aver-
564, 573 age ewe-lamb unit (PGCXE, PDCXE), by the grazable pasture (GPE *
584/8, 926/997 EGEF, DPE * EGEF), or by the mean daily available pasture during
the current week (GPE/7 or DPE/7).

238 EGEF is the ewe grazing efficiency factor on sparse pasture
(in hectares/sheep/day) and is equivalent to S in Noy-Meir (10).
The pasture intake due to the lambs is zero for the first 4 weeks
563/4 after lambing. Subsequently, the lamb intake on sparse pasture is
571 estimated as a fraction (WLAM/WEWE) of ewe intake. It is the mean
568 lamb intake per ewe and so is multiplied by the lamb-to-ewe ratio
566/7 (LER). The maximum intakes (PGCXE and PDCXE) are based on a value
for dry sheep (2 kg and 1.5 kg DM/sheep/d for green and dry
pasture, respectively), plus intake for lambs: 0.5 kg for singles
568 and 1.0 kg DM/d for twins (regulated by LER) in green pasture
and 0.2 and 0.1 kg/d, respectively, in dry pasture. The values
reflect the greater appetite of the sheep as the lactation demand
increases, and the smaller intake on dry pasture even when require-
712 ments are high. If the maximum intake capacity of the lambs
(MXDMIW) is greater than that part of the ewe intake that covers
lactation, then it will override the previous consideration. The
713 MXDMIW is dependent on lamb age (AGEW) and when the sheep are on
567 dry pasture, it is reduced in proportion to the digestibility of
226, 575/6 the dry pasture (DIGD/DIGG).

120, 151/2 Age-dependent maximum dry-matter-intake function for lambs (9)

AGEW (age in weeks)	MXDMIW (kg DM /lamb/d)
0	0
4	0
5	.3
6	.5
10	.72
12	.74
16	1.00
19	1.06
22	1.20
40	1.50
52	1.70

575/6 The digestibility of the dry pasture (DIGD) is relatively
226 high soon after the green season (HDD) and then drops as the sea-
son progresses and the sheep select out the finer, more digestible
parts (and some get blown away by wind)*. After a period of high
227 quality dry pasture (HQDPP), the digestibility of the feed drops
226 to a low value (LDD). After germination, the DIGD drops to 0.4,
and after 8 weeks most of the old pasture has decomposed or weather-
226 ed away and the new dry pasture again has high digestibility (HDD).

685/692, 688 2.4.2 Lamb liveweight: The mean birthweight of the lambs (IWLAM) is
512 dependent on the conception rate (LAMFR) and on the ewe's condition
at lambing (EWCON):

688, 139, 155 Effect of relationship between conception rate (LAMFR) and ewe condition (EWCON) on lamb birthweight

LAMFR (conception rate)	BIRWT (wt in kg/lamb)	EWCON (ewe condition)	ECONLM (reduction factor)
0	6.0	0	0
0.5	6.0	1	0
2.0	3.0	1.01	0.5
3.0	2.5	2.5	1.0
		5.0	1.0

* N. de Ridder, R.W. Benjamin and E. Eyal. Unpublished data from Migda experiments.

689 The liveweight change of the suckling lamb (LMWCH) that is
grazing with its mother depends mainly on the condition of the
691/2 mother (EWCON), on whether the pasture is green or dry, and on
153 the age of the lamb. It will also be influenced by feed supple-
697, 231 mentation to the lamb (with creep feeding for instance: D2SUPL),
568 and whether there are multiple births (LER). If ewe condition
is above 1, LMWCH is a function of lamb age (function LMWIT shown
below) and of pasture condition. The effect of pasture condition
is simply to halve the growth rate determined by function LMWIT
if the growing season has ended. If ewe condition is below 1,
691, 569/70 LMWCH is proportional to the DDM intake of the ewe above mainte-
nance with an upper limit of 350 g/day. If lambs are given sup-
689 plements (D2SUPL=1), the lamb growth rate is 350 g/day, regardless
of other factors.

The growth rate figure derived thus far is finally adjusted in accordance with the lamb-to-ewe ratio (function LGRT, shown below), with a maximum reduction of 30% for triplets (7).

153, 140 <u>Effect of lamb age (AGEW) and of multiple birth (LER)</u>
<u>on the liveweight change of lambs on pasture</u>

AGEW (weeks)	LMWIT (kg/lamb/d)	LER (lamb/ewe)	LGRT (reduction factor)
0	.25	0	1.0
4	.35	1	1.0
12	.35	2	0.8
20	.20	3	0.7
40	.10		
52	.10		

703/714 2.4.3. <u>Weaner liveweight</u>. The initial weight of the weaners is
normally the weight of the lambs at weaning. (If the model is run
344, 703 from midseason after weaning, the initial weight, IWW, is the
weight on the starting day.) At the end of the dry season (PLOW =
1), when weaners that have not yet been sold are hoggets retained
for breeding, the weaners are moved to the ewe category and weaner
705 weight is zeroed. The weaner liveweight change (WLWCH) depends on
706 its feed balance above maintenance (WFBAL) and on a conversion

efficiency of digestible dry matter to liveweight, which is
703 dependent on the weight of the weaner (WWNR). Thus, WLWCH = WFBAL* 0.62 * ECWT

where WFBAL = feed balance, in kg DDM/weaner/d,

0.62 = conversion to liveweight change (8), and

ECWT = efficiency factor.

The values of the efficiency factor are as follows:

122, 154

Weaner weight (kg) (WWNR)	Efficiency factor (ECWT)	Reference
2	0.77	(3)
42	0.55	(9)
55	0.50*	E. Eyal*

706 The weaner feed balance (WFBAL) is relatively straightforward,
being the difference between DDM intake (from green and dry pas-
708 ture; and from supplementary feed, SUPPWC) and the weaner require-
229 ment for maintenance (= KMNT * $WWNR^{0.75}$, where KMNT for weaners
is the same as that for ewes, 0.04). The green and dry pasture in-
710/11 takes (WGPI and WDPI, respectively) are limited by the age-depend-
712 ent intake function MXDMIW (see above for lambs), or by the
710/11 grazing efficiency (EGEF) on sparse pasture or by the amount of pas-
ture available. The amount available is the amount of forage on
953/966 the pasture minus an ungrazable residual that varies with the
amount of biomass (see "Grazing management" below).

2.5. Feed supplementation

633/678 2.5.1. Ewes. As the Migda model is designed to analyze management options in a context where supplementation is feasible, some practices which are considered minimal for proper sheep husbandry are built into the supplementation routine, and other possible supplementation practices are left as open management options. Thus, if grazing is deferred because of pasture scarcity, the sheep are maintained by supplementation. Before joining and lambing, the sheep will be given supplementary feed if necessary ("flushing" and "steaming up").

* Unpublished data.

Supplementation is based on concentrate feed; straw and hay
if available from stacks on the farm; and cotton-gin waste - which
is a very cheap roughage with a dry matter digestibility somewhat
higher than that of straw (0.5 compared with 0.4 for straw and
228 with 0.6 for hay - DIGCW, DIGS, DIGH, respectively - parameters
that can be adjusted if necessary). The calculations for supple-
mentation are based on DDM.

641/2 The amount of available DDM per day in hay (AVHAY) and straw
(AVSTR) is calculated. If the sheep are on pasture and the pasture
281 intake is greater than a set minimum (TULP), and ewe condition
225 (EWCON) is above a threshold value (ECSF), then there is no sup-
plementary feeding, even for flushing and steaming up. However,
if ewe condition is below ECSF, ewes will be given supplementary
646/7 feed for flushing (from 4 weeks before joining until 2 weeks
after) and for steaming up (from 4 weeks before lambing until 2
666/676 weeks after). At other times ewes will be given supplementary feed
661, 230 for maintenance only if it is set as an option (D2SUPE = 1) or if
661, 226 ewe condition drops below a preset danger point (CRASH). Supple-
651/8 mentation for flushing and steaming up is aimed at providing a
652 fraction above maintenance, DIGDME * (1 + FLUSH), where DIGDME is
569/70, 229 the DDM requirement for ewe maintenance and FLUSH is the extra
651 fraction above maintenance. If hay is available, it will be given
(SUPPEH); if it is not, or is insufficient, the required amount
656/8 of DDM will be given as concentrate feed. If the hay requirement
653 (SUPPEH) is greater than 1.5 kg DDM/day, the excess will be given
as concentrate.

665/676 Supplementation for maintenance is based on cheap roughage,
straw, or cotton gin waste. Straw will be given if it is available
770 on the farm (SSTAK), otherwise cotton-gin waste, which is regarded
666 as always available, will be given. Straw supplementation (SUPPES)
569/70 is the difference between DDM requirement for ewe maintenance
(DIGDME) plus lamb requirement (for maintenance and liveweight
gain) and the pasture intake from both green and dry components.
675/6 If no straw is available, or if it is insufficient, the straw re-
669/70 quirement will be made up by cotton gin waste (SUPECW). Also, if the
DDM straw requirement is > 1 kg, the difference will be made up with
cotton-gin waste up to a daily DDM requirement of 1.25 kg/ewe; any-
671/3 thing above that will be given as concentrate feed (SUPPEC).

682 Ewe supplementation from all sources is summed up in SUPPE.

694/9 2.5.2. Lambs. Concentrate only is used for supplementary feeding
of lambs. No supplements are given during the first 4 weeks after
697/8 birth. If lamb supplementation is a feasible option (D2SUPL = 1),
565 it will be implemented only if ewe intake of green pasture (EGPI)
566 is < 90% of ewe potential intake (PGCXE). The actual amount of
concentrate given (SUPPLC) will be twice the lamb maintenance re-
699 quirement (2 * DIGDML) multiplied by the feed deficit of the ewe,
697/8 expressed as (EGPI - DIGDME/DIGG)/(PGCXE - DIGDME/DIGG),

565 where EGPI = ewe green pasture intake (kg DM/ewe/d),
569/70 DIGDME = ewe maintenance requirement (kg DDM/ewe/d),
226 DIGG = digestibility of green pasture (kg DDM/kg DM), and
566 PGCXE = potential green pasture intake (kg DM/ewe/d).

699, 229 The constant (KMNT) used in the calculation of lamb mainte-
nance is the same as that used for the ewes and the weaners.

707/8 2.5.3. Weaners. Feed supplementation of weaners is considered
only if it is allowed as a feasible option (D2SUPW = 1). If it is,
707 then the supplement consists of concentrate only (SUPPWC). The
amount given, in kg DDM/weaner/d, is the least of one of the fol-
lowing:

707, 233 a) a pre-set ceiling supplementation level (MXWSUP);
b) the difference between weaner potential dry matter intake and
709/712 actual green and dry pasture intake (WDPDF);
707/8 c) the DDM requirement for maintenance plus the requirement for
233 minimum weaner growth (MINWGR) minus weaner intake of green
708, 710/11 (WGPI) and dry pasture (WDPI).

The weaner pasture intake is described in section 2.4.3.

770/797 2.6. Supplementary roughage availability

Whereas cotton gin waste represents a cheap low-quality roughage that is freely available and can be stockpiled to ensure year-round availability, straw and hay are produced on the farm and can be used only if available from the farm's stacks. The hay is meant to be wheat hay that is produced in years when the wheat biomass is sufficient for a hay harvest, but the chances of harvesting a grain crop are low. Part of the "wheat area" can be parameterized to represent a forage or hay legume and the pasture

can also be cut for hay by appropriate parameterization, but these
options have not yet been implemented.

771/3 2.6.1. Straw. A straw-stack (SSTAK) is maintained which can start
330, 345 from scratch (ISST=0) or from an available straw supply (ISST > 0).
The straw is monitored in kg/ha. Straw is added to the stack by
baling straw from harvested wheat fields, and is removed by use
771 and, if in excess, by sale. The use is SUPPES * NEWES * 7/DIGS,
666 where SUPPES = daily straw requirement (kg DDM/ewe/d),
509 NEWES = number of ewes/ha,
7 = conversion of the daily requirement to the weekly requirement,
228 and DIGS = digestibility of the straw (kg DDM/kg DM).

771, 774 The sale of straw (STSELL) is the excess above a maximum
amount (SSTAK - MXSST), if there is an excess and it is sold at
295 the end of the agricultural year (PLOW = 1). The MXSST is based on
274, 244 the estimated maximum number of weeks of straw supplementation
(WSTS), the planned number of ewes (INEWE), and the daily ration
(1 kg).

773 The amount of straw baled (BALST) is calculated separately
75 for each wheat subsection. The option, D2BS, can be invoked or
248, 824, 829 suppressed by adjusting the parameter SOP (= 1 or 0, respectively),
834, 839, 23 the value of which is passed on to D2BS in the pasture growth sec-
814 tion (see below). The actual decision to bale straw (BAYL) depends
first on whether the amount of balable straw in the wheat area
842 (DVW * B) is greater than a threshold value (T); and second on
285/292 whether all of the straw will be grazed (E > DVW * FRW) or not.
276, 278/9 B, T and E are the fraction that can be baled, the minimum thresh-
old for baling (kg/ha) and ewe straw requirement calculated as:
288 INEWE * 10.5 * (PTIM - ST)/(1. + WASTE)
224, 200 where INEWE = planned number of ewes/ha,
10.5 = stubble grazing intake (kg/ewe/wk),
355, 175 PTIM = plowing week when stubble will be turned over,
359, 177/8 ST = straw baling week, and
283, 271 WASTE = fraction of residue wasted by trampling, wind effects, etc.

The amount of straw baled for each wheat section, in kg/ha
(BLST), is thus
75 BLST = D2BS * DV * B * BAYL

where DVP is the amount of dry biomass in each wheat section.
773 The total amount of straw baled is summed up from the baled straw
yield of each section.

(In the present model, which is written in CSMP, the vegeta-
20/79 tion calculations are defined in a MACRO (GROGV) which is then
817/840 written out with appropriate variable substitution for each of
the pasture and wheat sections.)

775/8 2.6.2. Hay. The operation of the hay stack (HSTAK) (addition,
utilization and sale) follows the straw-stack procedure in most
details. The differences are related to leaf loss in the swath
and to the decision to bale hay. The fraction of dry matter lost
777, 279 during drying is represented by HLOSS.

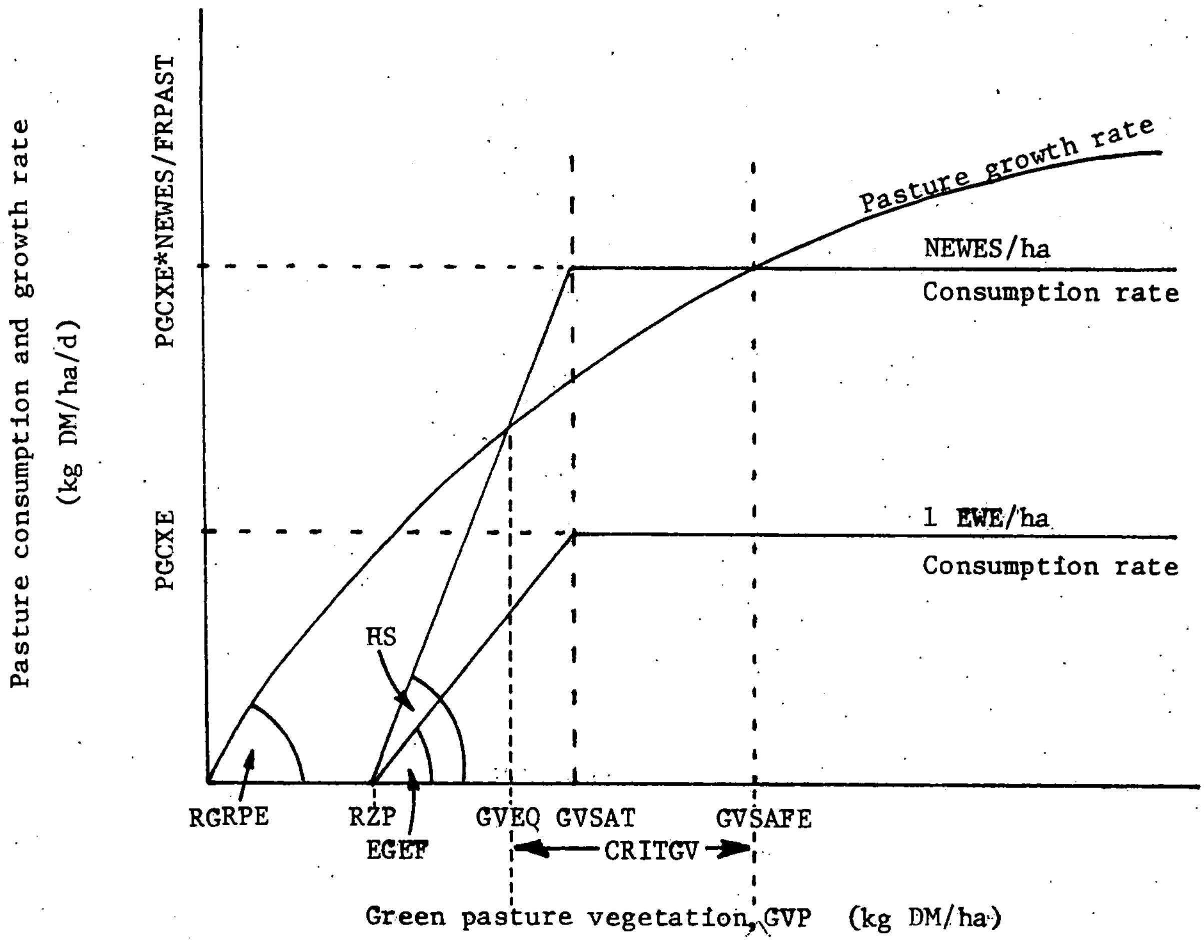
The option to bale hay, like straw, can be invoked or sup-
275, 23, 77 pressed (parameter HOP = 1 or 0, which is transferred to D2BP in
77 the MACRO GROGV). The actual decision to cut hay (D2BH) will de-
pend on whether the following conditions are met on the day the
403, 358, 174 decision to cut must be taken (HAY), which is set here as week
11 (mid-March):

77 a) total biomass (green and dry) is > 2000 kg/ha, and green bio-
mass is at least 1000 kg/ha; and
78, 279 b) grain/straw ratio is less than a threshold value (THGSR); and
78 c) the growth conditions (soil moisture) are unfavorable for a
813 good grain harvest (TUDRY = 1). This occurs if the exogenous
381 growth control function, SM, is < 0.2 (of potential growth).
76 If D2BH = 1, then the amount of hay that will be cut is the
excess above 500 kg/ha green biomass plus the excess of 1000 kg
of dry biomass.

590/630 2.7. Grazing management

590 The animals graze year round (DEFER = 1) on pasture, wheat
stubble or green wheat unless they are moved to corrals (DEFER =
0) because of pasture management considerations. Before germina-
414, 419 tion of the vegetation (GTIM) and after a last deferment date
357, 175 (LDTIM, beginning of March), the sheep are kept on pasture. If
pasture is sparse during this period, the sheep may or may not
633/676 receive supplements (see section 2.5.1), but they are not removed

Fig. 1. Relationship between pasture consumption and pasture growth during the early exponential growth phase (after ref. 9).



GVSAT	= PGCXE/EGEF + RZP	(kg/ha),
GVSAFE	= (PGCXE * NEWES/FRPAST)/RGRPE	(kg/ha),
RGRPE	= (GRVP/7)/GVP	(/day),
GVEQ	= HS * RZP/(HS - RGRPE)	(kg/ha),
HS	= NEWES * EGEF	(/day),
CRITGV	= (GVSAFE + GVEQ)/2	(kg/ha),
PGCXE	= potential DM consumption/ewe/ha	(kg/ha), and
RZP	= residual ungrazable pasture	(kg/ha).

from pasture. Grazing deferment can take place during the green season if the amount of green biomass is below a threshold that endangers the productivity of the pasture under the given sheep population density (= stocking rate). The criteria for deferment used in this model are based on the concepts developed by Noy-Meir (10). A graphic presentation of the relationships between pasture growth and consumption is given in Figure 1. The following values are defined:

603 a) GVSAT = minimum amount of green vegetation necessary for daily sheep intake to attain satiation;

604 b) GVSAFE = amount of vegetation sufficient to prevent green pasture biomass (GVP) from being grazed down to a low equilibrium point (GVEQ);

607 c) CRITGV = a value below which sheep should be taken off the pasture in order to prevent grazing down to GVEQ (here taken as an arbitrary value between GVSAFE and GVEQ);

606 d) GVEQ = a low equilibrium point at which the growth rate of pasture equals the sheep consumption rate;

604 e) RGRPE = relative growth rate of the pasture being grazed by ewes;

221, 233 f) EGEF = ewe grazing efficiency (ha/sheep/d); and

605 g) HS = NEWES * EGEF.

If the sheep are on pasture, grazing will be deferred (DEFER = 0) if any of the following conditions is met:

609/10 a) the relative growth rate of the pasture (RGRPE) is less than the herd grazing efficiency times a safety factor (SAFFE); and both green and dry pasture vegetation (GVP and DVP) are less than GVSAT;

610/11 b) the green pasture vegetation (GVP) is greater than GVSAT, but flock consumption rate per day times a safety factor (SAFF) is greater than daily pasture growth rate;

612/13 c) ewe green and dry pasture consumption (EGPI1 and EDPI1) is less than a threshold value (TULP); or

613 d) a pre-set period after germination (DEFW) has not elapsed.

Implementation of deferment will also be conditional on additional considerations:

616/7 i. less than two previous deferments have taken place in the current season;

618 ii. the last deferment date (LDTIM) has not yet passed;

618 iii. if the pasture is not being grazed then deferment will be continued;

616, 620/1 iv. if the pasture is being grazed, the criteria are temporarily relaxed in the event of later improvement in pasture growth rate. In this case deferment will not be implemented even if the herd daily consumption rate is greater than the daily growth rate as long as the amount of green pasture vegetation is greater than CRITGV or GVSAT, whichever is smaller.

If the pasture is not being grazed (DEFER = 0) and any of the
625 above criteria are not met, then the sheep will be returned to pas-
617 ture (DEFER = 1). Only two deferments and returns are allowed
during the growing season, i.e., grazing will not be deferred for
a third time within one grazing season.

925/995 2.8. Paddock allocation

722/765 The decisions that must be made are: whether or not to graze the pasture; if the pasture is not grazed - whether or not to graze the green wheat or wheat stubble; and if the wheat area is grazed - which subsection to graze.

757/8 Entry of ewes and weaners into pasture or wheat is monitored
by AINCRE and AINCRW, which represent the accumulated increment
of wheat paddocks grazed by ewes or weaners: If AINCRE = AINCRW =
0, then there is no grazing of wheat fields, green or dry; if
AINCRE = AINCRW = 1 - 4, then 1 to 4 wheat subsections are grazed.
These subsections are incremented one at a time as they become
grazed out and insufficient pasture is available to which to re-
757/8 turn. At harvest time (HARV1 = 1) all wheat subsections are opened
up to grazing the aftermaths. The wheat fields are closed to graz-
757, 750 ing (-AINCRE * ZAINC) after plowing (PLOW = 1), after the booting
750 stage (ASMWK > NOGEF); and when the amount of vegetation, green
750 and dry, is less than the ungrazable residual (GVW + DVW < RZW1).

The decision to graze the green wheat is implemented by
722/747 the variables INGWE and INGWW, which become unity and pass on the

957/8 value to AINCRE and AINCRW.

The decision to put weaners on green wheat is taken when weaners
728/9 are to be raised on pasture and at weaning the available pasture
274, 243 DM is less than the ewe requirement until the next germination
date. Weaners already grazing green wheat will be allowed access
730/1 to an extra wheat subsection if weaner live-weight gain (WLWCH) <
200 g/d and the available green and dry biomass in the wheat subsection being grazed (GPW and DPW) is less than GVSAT/1.5. The division by 1.5 represents the lower satiation index of weaners compared with ewes.

The decision to put ewes on green wheat is taken if one of the following conditions is met:

735/9 a) the wheat has passed an early establishment stage when
736 grazing is not allowed (GTIM + EWG), the animals are off pas-
282, 269, 590 ture (DEFER = 0), green wheat grazing is allowed in principle
231 (D2GGW = 1), and the amount of dry matter in the wheat fields
735 is greater than either a minimum amount for grazing (MINW4G)
738 or the amount necessary for satiation, times a safety factor
602, 281 (GVSAT * SAFF), and the ewes are not receiving supplements;

740 b) the growing season has ended (EGS = 1) and the grain yield
836, 53 of the least disturbed wheat field (WG4) is less than a mini-
275, 246 mum necessary for a harvestable wheat crop (MINGH); or

741/2 c) it is time to decide whether to cut the wheat for hay (HYTIM)
358, 174 and the total above-ground biomass is less than a minimum for
279 hay cutting (WFAIL).

745/6 If one wheat subsection is already being grazed (AINCRE $\geq$ 1)
and the biomass available for grazing is less than half that necessary for satiation, then the sheep are allowed to move into the next subsection.

Once the decision on wheat grazing has been taken and AINCRE
757/8 and AINCRW have been updated, the appropriate paddock must be al-
925/995 located. This is described in the subroutine* PADOK. It is called
583/5, 717/20 separately for ewes and weaners. In the subroutine the calls are

* This subroutine has been used instead of a MACRO in order to save space in the CSMP translation table.

925, 585, 720 differentiated by EWOWN (0.5 for ewes, 1.0 for weaners), where
958, 966, 977/8 EWOWN is a factor used to multiply the residual biomass. The lower
value for ewes implies that the ewes are better able to utilize
sparse pasture than the weaners.

934/945 If AINCRE or AINCRW is zero, then none of the wheat subsec-
974/8 tions is allocated (ZP = 1). Instead, the sheep will be regarded
as being in pasture and the values of green and dry pasture will
977/8 be returned as GPE,DPE or GPW,DPW, depending on whether a ewe or
weaner call is being processed. If AINCRE or AINCRW > 0, then
wheat can be grazed and the number of subsections from which a
934/940 permissible choice can be made is determined by the value of
AINCRE or AINCRW. From these, the subsection with the highest
948/9 green and dry biomass is determined. The choice will be made by
951/966 green biomass unless the amount is < 500 kg DM/ha and the amount
of dry biomass is more than double the amount of green biomass.
958, 966 In the latter case, the choice will be made by dry biomass. The
appropriate ungrazable residual biomass (RZW(N) * EWOWN) is then
48/50 subtracted from the dominant fraction (green or dry), RZW changes
as the canopy grows. If the available wheat pasture is less than
968/970 the amount needed to ensure intake of about 1.5 kg/sheep/d and
the available pasture for grazing, then the pasture paddock will
be allocated instead of a wheat subsection.

If the pasture is allocated, then the ungrazable residual
will be deducted from green or dry, whichever is the dominant
fraction. If it is deducted from dry, then a minimum ungrazable
976, 280 residual (MNRZ) will still be deducted from the green, implying
that when the plants are nearly dry, some of the green is unavail-
able - as stem-base or other parts that are difficult to graze.

980/1 If the biomass in the pasture allocated is less than the un-
grazable residual, the available pasture is zero. The subroutine
986/993 also returns the number of the allocated subsection, if one is
chosen,

20/78 2.9. Pasture and wheat growth

The changes in the amount and composition of the vegetation
are calculated separately for the pasture and for each of the
wheat subsections. The basic calculations are defined in MACRO

20/78, 817/839 GROGV, which is then invoked as necessary. The MACRO is divided into the following sections:

1. green vegetative biomass,
2. residual green biomass,
3. seed production and grain harvest,
4. dry vegetative biomass, and
5. balable straw and hay.

The output and input variables of MACRO GROGV are summarized in
Table 1 Table 1. The line references cited lead to the MACRO definition,
the invocations and the sources of input variables.

26/46 2.9.1. Green vegetative biomass. The green biomass is initiated
28, 418, 53 at germination (GERM = 1) from the pasture seed stock in the soil
22, 273 (GRAIN) or from sown pasture, or wheat seeds (IGV = IGVP, IGVW) - a
818, 823 .... fraction of which, FRG, is converted into above-ground biomass.
281, 29, 35 FRG is set at FRGERM for pasture seeds and as 1 for wheat seed.
43, 44 The balance of growth rate (GRV), death rate (DRGV), consumption
(intake) rate (ING), and green vegetation removal by cutting for
28 hay is summarized by NGRV (net growth rate of vegetation). After
404, 354, 174 the grain harvest date (HARV1), there is no more green vegetation
until the following season.

35/39 2.9.1.1. Growth rate of vegetation. The calculation of the growth
rate of the vegetation (GRV) is dependent on exogenous information
on the growth curve of undisturbed vegetation for the current
39, 147/9 year. This can be data actually measured in the field; output data
of a canopy growth model like ARID CROP or PAPRAN (5,6,12); or even
predicted values based on rainfall probabilities. From the growth curves a relative growth factor (SM) is calculated which relates the measured growth rate to a potential growth rate. The potential growth rate is a relative growth rate (PRGR) during the exponential phase of growth, and a linear growth rate (MXGR) thereafter, the transition being made when the green biomass > 1900 kgDM/ha. The values for SM are generally between 0 and 1 but can conceivably be above unity if measured growth rates are above the assumed potential growth rates. The SM values are calculated in a separate
141/5 program (see Appendix IV) and are entered as FUNCTION SMT. The

TABLE 1. INPUT AND OUTPUT VARIABLES OF MACRO GROGV

Output variable	Input variable	Definition (all vegetative biomass on a dry-matter basis)		Value or Parameter pasture	Wheat	Line ref.
GV		green above-ground phytomass	kg/ha	GVP	GVW1-4	28,817...*
DV		dry above-ground phytomass	kg/ha	DVP	DVW1-4	66,817...*
GRV		growth rate of green vegetation	kg/ha/wk	GRVP	GRVW1-4	35,817...*
DRGV		death rate of green vegetation	kg/ha/wk	DRGVP	DRGVW1-4	43,817...*
ING		rate of green pasture intake of sheep	kg/ha/wk	INGP	INGW1-4	44,817...*
TRG		rate of assimilate translocation to grain	kg/ha/wk	TRGP	TRGW1-4	46,817...*
LOSS		trampling and weathering loss of DM	kg/ha/wk	LOSSP	LOSSW1-4	68,817...*
IND		rate of dry pasture intake of sheep	kg/ha/wk	INDP	INDW1-4	69,817...*
GRAIN		seed or grain produced	kg/ha	SEED	WG1-4	53,817...*
GHARV		harvested grain yield	kg/ha	SHARV	WHARV1-4	59,817...*
BLST		straw baled	kg/ha	BLPS	BLST1-4	75,817...*
BLHY		hay baled	kg/ha	BLPH	BLHY1-4	76,817...*
P		primary production	kg/ha	PPP	PP1-4	41,817...*
RZ		ungrazable residual green biomass	kg/ha	RZP	RZW1-4	49,817...*
	IGV	sown pasture or wheat seed	kg/ha	IGVP	IGVW	28,818...,273
	FRG	fraction of seed to initial biomass	-	FRGERM	1	28,818...,281
	ETIME	time of phenological maturity	week	EPTIM	EWTIM	42,818...175
	EIW	ewe in wheat subsection	-	EGRZP	EIW1-4	60,44,181, 585,720
	WIW	weaner in wheat subsection	-	WGRZP	WIW1-4	60,44,181, 585,720
	FR	fraction of total farm area	-	FRPAST	FRW	45,818..., 273,776
	ETF	age of vegetation at seed fill initiation	week	EPTF	EWTF	46,818...,277
	LTF	age of vegetation for unrestricted seed fill	week	LPTF	LWTF	46,818...,277
	TFVS	fraction of assimilate translocated to seed	-	TFVSP	TFVSW	55,819...,278
	GRE	flag for wheat grazed by ewes	-	0	GRE1-4	57,819... 505,172
	GRW	flag for wheat grazed by weaners	-	0	GRW1-4	57,819... 585,720
	PLOW	flag for plowing day	-	0	PLOW	49,66,819..., 402
	HARV	flag for grain harvest day	-	0	HARV	57,819...,406
	D2BP	option to cut for hay	-	0	HOP	77,819...,275
	D2BS	option to bale straw	-	0	SOP	75,819...,275
	IS **	initial seed production	kg/ha	ISP	IS1-4	53,819...,334
	IG **	initial green biomass	kg/ha	IGP	IG1-4	28,819...,335
	ID **	initial dry biomass	kg/ha	IDVP	ID1-4	66,819...,336
	IP **	initial primary production	kg/ha	IPP	IP1-4	41,819...,337
	IRZ **	initial ungrazable residual	kg/ha	IRZP	IRZ1-4	49,819...,338
	IH **	initial grain harvested	kg/ha	0	IH1-4	59,819...,339
	PS	flag for pasture (=1) or wheat (=0)		1	0	45,819...

* Calls for wheat subsections can be located in the vicinity of the first call, e.g. 817 for pasture 1, 821 for subsection 1, 826 for subsection 2, 831 for subsection 3, 836 for subsection 4.

** Initial values for runs that do not begin at TIME=0; thus, "initial" refers to value at TIME equals non-zero start run time.

measured growth values are used by the same routine to calculate
146/50 a growth curve based on weekly interpolated values, FUNCTION MGCT.

The SM values are used to calculate a weekly exponential
809 growth rate (WEGR) and a weekly linear growth rate (LINGR), and reflect the growing conditions for the current week. These are determined by soil moisture and fertility, climatic conditions, and the state of an ungrazed growing crop or pasture canopy. The growth rate calculated in the model is also dependent on the green
35 biomass, GV. Here, too, the growth rate during the early stages, upto 1900 kgDM/ha, is based on exponential growth, and on linear growth thereafter, but because of different initial values and defoliation due to grazing, the calculated rates will be different from the measured values that are based on undisturbed growth. To this point, it is assumed that there is no feedback from the state of the vegetation to the current SM value. This is clearly not true, but could be a fair approximation where there are large differences in SM over the season and from season to season. The main feedback on the SM is most probably due to the effect of different growth rates on the soil water balance. In order to take this into account, a "soil moisture reserve" is postulated which starts at zero but which is increased whenever the calculated growth rate is less than the measured. This "moisture reserve" improves growing conditions for subsequent growth by increasing the value of SM. If, as a result, calculated growth is greater than measured, the "soil moisture reserve" is depleted. It is also continuously depleted by an evaporation factor which increases with potential evaporation as the summer progresses. The amount of water added to and depleted from the reserve depends on the amount of growth and on a water-use efficiency factor. This is a mimicked construction which, for all its artificiality, does incorporate the main characteristics of the soil moisture - vegetation growth feedback pathway. Whether it improves the estimation of growth rates of grazed canopies remains to be seen.

The actual computations are as follows:

35/9 The net growth rate of the vegetation (GRV) is exponential (EXGR * GV) as long as GV < 1900 kg/ha, and linear (LINGR) otherwise.

Growth is partitioned into vegetative parts and seed formation and
35, 46 fill by a factor (TRG) that controls translocation to grain. This
46 starts to operate soon after flowering, here taken as 13 weeks af-
389 ter germination (ASMWK ≥ 13). During the first 2 weeks, seed fill
46 proceeds at a relatively slow rate (ETF) as sink sites are being
46 formed; subsequently, it proceeds at a faster rate (LTF). These
277, table 1 translocation rates are different for pasture and wheat, but onset
of flowering is regarded as happening at the same time for both
35, 42 vegetation types. Growth and translocation continue (DVS = 1) as
long as there is green biomass and as long as the vegetation has
not reached full maturity. This will be attained within 25 weeks
42, 175 after germination or at a photoperiodic end-date (ETIME), whichever
table 1 is earlier. ETIME has different values for wheat and pasture.

36 The weekly exponential growth rate (EXGR) is the greater of
809 (a) WEGR, which is based on a potential relative growth rate
809, 382 (RGR), multiplied by the growth condition factor (SM), or (b) a
36, 308, 303 weekly potential growth rate (PRGR * D7), multiplied by the sta-
38 tus of the moisture reserve, whichever is the greater. The status
308, 301 of the moisture reserve (AVW) is defined as AVW/WTPG, where WTPG
is the amount of available moisture necessary to ensure no mois-
37 ture limitation to growth. The linear weekly growth rate (LINGR),
280 similarly, is a maximum growth rate (MXGR) multiplied by SM or
AVW/WTPG, whichever is greater. The value of AVW/WTPG is in both
cases between 0 and 1.

The available moisture reserve (AVW) starts as zero (AVWI = 0)
or, if the simulation begins in mid-season, with whatever the sta-
38, 39 tus is at that point in time. Whenever the measured growth rate (MGR)
35 exceeds the actual growth rate (GRV), the moisture that was not
exploited will be added to the moisture reserve, and vice versa.
39 The measured growth rate (MGR) is the derivative of the measured
146/150 growth curve (MGCT), calculated at mid-week. The conversion from
38, 309 kg/ha to mm is effected by multiplying the difference by M/10,000,
where M is the ratio between growth and transpired water, taken
here as 200 kg water/kg DM. The moisture store is being constantly
depleted by surface evaporation, calculated as a constant fraction
38 (EVBS) of AVW which increases in the summer (SINFAC = 3) and de-
38, 378 creases in the winter (SINFAC = 1).

29, 43 2.9.1.2. Death rate of vegetation. The death rate of the green
vegetation (DRGV) applies only to the green vegetation that is not
grazed in a given week. It can occur because of senescence
277 (SENESC) or because of excessively dry conditions, which prevail
when SM < 0.1, in which case the death rate rises to a more severe
278 drying rate (DRYR). If there is green biomass in the field at
wheat harvest time (HARV1 = 1), whatever is not translocated to
43, 278 seed (TFVS) is transferred to the dead biomass fraction.

29, 44/5 2.9.1.3. Green pasture intake. The amount of green vegetation in-
gested by the sheep (ING) is the amount consumed in one week by
563/5, 711 both ewes (EGPI) and weaners (WGPI), per hectare of the pasture
or wheat paddock that is being grazed. They cannot graze any more
green vegetation than is available in one week (GV/DELT) and will
44 not consume vegetation unless they are on pasture (GRZN = 1). The
green biomass consumed by ewes (EGPI) represents the pasture con-
sumed by both ewe and suckling lamb. It is limited by the physio-
567 logical intake capacity of the ewe and lamb (PDCXE) or by the
585, Sect. 2.8 availability of the pasture for ewes (GPE) and the grazing effi-
233 ciency of the ewes (EGEF). The green biomass consumed by weaners
712, 151/2 (WGPI) is limited by an age-dependent maximum intake rate (MXDMIW)
or by the available pasture and the weaner grazing efficiency
233 (EGEF), here taken as equal to that of the ewe.

48/50 2.9.1.4. Available green pasture. The green pasture available for
grazing in any paddock is the standing green biomass minus the un-
49, 280 grazable residual (RZ), which is very little (MNRZ) soon after
germination when the plants are young, but increases as the plants
become established and develop tougher stem bases. The rate of in-
50 crease (IGVR) is assumed to be zero until the plants start flower-
ing (TRG > 0), after which it increases at a fixed proportion
46 (0.012) of the growth rate (GRV). The proportion is derived from
the observation that after a heavy growth of pasture, reaching
about 10 t/ha, about 600-700 kg will remain as ungrazable residue
after a summer of heavy grazing. This is not exactly the same as
green ungrazable residual, but is a fair approximation. There will
be much less ungrazable residual in a poor year, as has been ob-

served*. No distinction is made in the present model between wheat and pasture with regard to RZ; however, different growth rates due to grazing will result in different residuals, the ungrazed vegetation ending up with a larger RZ.

49 The RZ at the end of the green season is maintained until the
field is plowed in the case of wheat paddocks (PLOW = 1), and until
418 the next germination date (GERM = 1) in pasture paddocks. After
germination, RZ is reset to MNRZ in both types of vegetation.

41 2.9.1.5. <u>Total primary production</u>. Total primary production (P) is
calculated as the integral of the growth rate of the vegetation,
including seed growth. It is zero at the beginning of the season
(IP = 0), though for runs that begin in mid-season, IP would be
set to the value attained at the beginning of the mid-season runs.
In the case of primary production it is unlikely that this would
be a measured value but would be in the output from a separate
453/7 run. The total primary production is used to determine the level
465 of productivity attained in a given year, which influences the
price of hay and straw. As the wheat may be grazed, the primary
production is a more reliable measure of how good or bad a year it
465, 837 was. For this purpose, we take the primary production (PP4) of the
wheat paddock least likely to have been grazed.

52/60 2.9.2. <u>Seed production and harvest</u>. The amount of seed produced
55 (GRAIN) depends on the rate of seed fill (GRGR) which begins as
46 soon as TRG > 0, and is calculated as GRV * TRG At the end of the
growing season, a fraction of the remaining green biomass is trans-
located to the seed (TFVS * GV). If the amount of seed exceeds half
35 the total biomass (GRAIN > (DV + GV)), seed fill will stop. It can
continue subsequently if the amount of vegetative biomass has in-
creased in the meantime. If a wheat field is grazed after booting
55, 56 (G = 0), then grain growth is prevented. The photosynthate that
should have gone to the grain is not re-allocated to the vegetative
organs, as it appears that grazing wheat late in the season removes
most of the leaves and reduces photosynthesis drastically (2).

* Benjamin, R. (1979) Unpublished data from summer pasture experiment, Migda, Israel.

Grazing pasture, on the other hand, does not prevent seed fill
(G = 1) but will reduce it whenever the growth rate of the vegeta-
56, 819, table 1 tion (GRV) is reduced because of grazing (G = 1. - min(1., GRE +
21/78 GRW)). GRE and GRW are set at 0 for pasture calls to MACRO GROGV;
for wheat calls, GRE and/or GRW will be set at 1 if the paddock in
584/5, 719/20 question was grazed during the reproductive stage. This is deter-
926/996, sect.2.8 mined in calls to SUBROUTINE PADOK.

53 Seed biomass can be reduced by germination, harvest, seed
54 predation, or burial by plowing. At germination (GERM = 1) the a-
mount of seed in the soil (GRAIN) is reduced by the fraction that
germinates. This fraction is immaterial for wheat, as virtually
none of last year's grain crop remains. For pasture, especially
where no pasture seeds are sown, the regrowth depends on the amount
of seed available (GRAIN) and its germination rate. It may be that
very little was available for germination in a given year (because
of poor production in the previous year or heavy ant predation (8,
11); in this case there would still be germination from stocks in
54, 274 the soil. A minimum seed stock (MINSS) is thus always available
for germination.

55 In the event of wheat being cut for hay (D2BH = 1), the seeds
76, 67 will be transferred to the cut hay. The grain yield harvested
53, 57, 278 (GRHAR) is a fraction (FRHARW) of the crop. The rest remains in the
field (as GRAIN). (Again, fields grazed during the reproductive stage
406 are not harvested.) The grain will be harvested (HARV = 1) only if
275, 406 the harvestable grain yield is above a threshold level (MINGH);
otherwise, the grain will remain in the field and will be available
for grazing. (The decision to harvest could be optimized less
crudely than in this procedure, especially where animal density is
high and concentrate feed will be fed anyway.)

58 All the causes of seed loss in the pasture paddocks (ant, ro-
dent, bird predation, grazing) are lumped together in a relative
279 seed loss factor (SLWK) which results in an exponential decrease
in the amount of available seed (GRAIN) from seed dispersal onward
58, 354, 174 (one week after harvest time, HTIM + 1). With SLWK set at 0.1, the
seed stock (GRAIN) is halved about every 7 weeks.

The grain harvest is stored (as an integral, GHARV) until it is sold and accounted for.

64/70 2.9.3. Dry vegetative biomass. The amount of dry above-ground bio-
67, sect 2.9.1.2. mass (DV) changes as green tissue dies (DRGV) and, as the dry ma-
70 terial is removed by grazing (IND), by loss due to trampling and
69, 75/6 weathering (LOSS), and by the harvesting of straw or hay. The
66 seeds are added to the dry biomass when wheat is grazed in the re-
56 productive phase (G = 0 in the wheat plots), and when the wheat is
cut for hay (D2BH = 1). In the latter event, it would not have been
56 grazed prior to being cut for hay (G = 1). All dry material is
66, 402 buried when the wheat fields are plowed at the end of the summer
(PLOW = 1).

Dry material that is not grazed or removed by harvest decreases
by weathering, wind loss, removal by ants, rodents, etc., and by
68, 810/11 trampling during grazing (LOSS). The losses (LOSS1) that are not
due to trampling are represented by four rate factors: a dry-mat-
810, 280, 259 ter loss on maturity (DMLOM), due to seed dispersal and predation;
282, 270 a dry-matter decomposition rate (DML2) which is operative during
811, 388 the early part of the wet growing season (ASMWK < 8); a weathering
282, 270 rate of new dry material (DML3) during the latter part of the grow-
282, 270, 388 ing season; and a summer weathering rate (DML1 when ASMWK = 0).
These rates are applied to the dry vegetative material that is not
grazed in a current week (DV/DELT - IND)*.

63, 283 The losses due to trampling (WASTE) are a function of the
grazing intensity, here represented by the intake of dry vegetative
69/70 material (IND).

The consumption of dry material by grazing (IND) is the sum of
572/3, 711/2 dry matter intake of ewes (EDPI) and of weaners (WDPI). The units
of IND are kg DM/ha/week for each vegetation type and paddock as
69 the daily intake rates are multiplied by seven times the number
572/3 of animals per hectare. The dry matter intake of ewes (EDPI) is the
intake of the ewe plus lamb and is limited by the potential dry
571 pasture intake of the ewes (PEDPI) when there is sufficient pasture,

* DV, a state variable, is divided by DELT in order to maintain unit-consistency with IND, which is a rate. Thus, the weathering rate factors are dimensionless in the present context.

233 and by the grazing efficiency of the ewes (EGEF) when the pasture
is sparse. The dry pasture intake of the lamb is zero for the
first 4 weeks, but subsequently is taken as proportional to the
571 ewe-intake by the factor WLAM/WEWE. The number of lambs per ewe
568 (LER) also influences the EDPI. The amount of dry pasture consumed
depends on the availability of green pasture and directly on ewe
563/5 green pasture intake (EGPI). It is assumed that only the difference
between potential dry pasture intake (PEDPI) and EGPI is consumed.
573 If EGPI is greater than PEDPI, no dry pasture will be consumed.
710 The dry pasture intake of the weaners (WDPI) is dependent on the
711 green pasture intake (WGPI) in a similar way. The maximum dry pas-
712 ture intake of the weaner (MXDMIW) is age-dependent and here is not
influenced by the digestibility of the dry pasture. The grazing ef-
233 ficiency factor (EGEF) is also the same for green and dry pasture.

75 The removal of dry vegetative material as straw (BLST) is op-
275, 824... erative only in the wheat fields when BLST = SOP = 1. The decision
814, 405, 359 to bale straw (BAYL) is taken 2 weeks after harvest time (BS = 1
177, 178 at HWEEK + W2BS), BAYL = 1 only if the amount of wheat straw that
814, 842, 278/9 can be baled (DVW * B) is greater than a minimum amount (T), and
288 if the ewe requirement for wheat stubble (E) is less than the
amount of available dry material in the field. The ewe requirement
224 (E) is the product of the number of ewes (INEWE), the weekly stub-
283 ble intake (10.5 kg DM/ewe/wk), and a wastage factor (1 + WASTE)
due to trampling while grazing. This is based on a rough estimate
of waste and on the assumption that the waste due to trampling and
that due to feeding straw in a corral, are of about the same magni-
49 tude. The ungrazable residual biomass (RZ) is included in the WASTE
factor in the present context. If straw is to be baled, only a
75, 278, 66 fraction (B) of the dry vegetative material (DV) can be collected
and the rest remains to be grazed if necessary.

77/8, sect. 2.6.2, If hay is cut (D2BH = 1), then the dry vegetation above 1000 kg/
68 ha (DV - 1000) will be removed as hay; the rest remains to be grazed
if necessary.

3. Management Options

A number of management options are built into the model in the sense that the criteria for decisions are fixed (e.g. the
77 decision not to cut wheat for hay (D2BH=0) if the total dry material is < 2 t/ha and the green material is < 1 t/ha). Many other criteria are fixed as default values, but can be changed simply
78, 279 by resetting parameters (e.g. the threshold grain-to-shoot ratio (THGSR) above which hay will not be cut). Other parameter changes can be made, albeit less conveniently, by changing the values on the input string to the various MACRO calls. For example, the option to cut the pasture for hay is eliminated by setting the
77 dummy variable (D2BP) to zero in the MACRO call for the pasture
819 paddocks (second parameter to the right of ISP). Again, if this is not to be regarded as a constant situation, the zero can be replaced by a parameter or variable for easier manipulation. (Changing fixed values in MACRO calls cannot be effected in reruns. The CSMP program must be re-translated and re-compiled. Thus, if dummy variables for specific MACRO calls are not to remain constant over a large series of runs, it is worthwhile to replace constants by parameters that can be changed from run to run or by variables that can be set by decision rules in the model itself.)

3.1. Land Management

The allocation of land between wheat and pasture is con-
273 trolled by the parameter FRPAST, defined as the fraction of total area under pasture, for which a standard setting of 0.5 is general-
276 ly used. Once FRPAST is set, the fraction of the farm under wheat (FRW) is set automatically. The wheat will then be subdivided into four equal sections (fields). These sections can be opened up for grazing if the necessary criteria are met (see section 2.8). Other manipulations are dependent on the type of farming system. Thus, if the farm is made all pasture (FRPAST=1), there is no point to setting special wheat parameters and _vice versa_. The combination of wheat and pasture can be set up to represent an alternating rotation between wheat and pasture or a fixed system where the pasture section is not rotated with the wheat, but the area allocated to wheat can be subdivided into legume and wheat.

3.1.1. Fixed ley system. This system is characterized by the fact that the pasture is not sown every year but regenerates from seed that has remained from the natural seed production of previ-
25, 818, 273 ous years. The amount of pasture seed sown is set to zero (IGVP=0). The model is set up so that the fixed ley is the default option.

3.1.2. Alternating ley system. Here the pasture is sown, so the amount and cost of seed and cultivation costs must be set. The relevant parameters are:

IGVP = amount of seed sown (kg/ha)

CPSEED = cost of pasture seed and cultivation (IL*/ha).

Since the pasture is cultivated, the PLOW parameter in the MACRO
49, 66, 819, 402 GROGV calls is set to PLOW (instead of zero as in the fixed ley). The present version is based on the pasture and wheat rotating every year, with no carry-over effects from one year to the next year taken into account. Longer pasture periods in a run over more than one year could be implemented by using the END CONTINUE option and setting IGVP to zero in the runs that represent years when the pasture is not sown. In this case a small alteration in the MACRO GROGV pasture call needs to be made. The MACRO dummy variable PLOW must be changed from zero to, say, PLOP (plow pasture). PLOP is then defined in the DYNAMIC section as PLOP = PLOW * PLOWP, and PLOWP is defined as a parameter. In years when the pasture is not plowed, PLOWP=0; in the year that it is plowed, PLOWP=1.

If the sown pasture is an all-legume pasture, the digestibility values have to be set to appropriate values (see section 6.4). The amount of seed sown (IGVP) would, as a rule, be one-quarter to one-half of that sown in mixed pastures.

817 3.1.3. Fallow. In the calls to MACRO GROGV, the values of some parameters in the input string can be adjusted (Table 1). The sections fallowed should have no vegetation, so the amount of seed

* When the computer program was written, the local currency was the Israel pound (IL); today it is the shekel (IS).

sown (IGV) would be set to zero (instead of the default value, IGVW). In the sections with wheat, the better growth due to water storage would have to be accounted for by adding AVWI to the input string in the MACRO definition and then defining separate initial reserve water in the wheat sections and zero in the following: <u>e.g.</u> AVWI1 = AVWI2 = say 50mm; AVWI3 = AVWI4 = 0. These values could be defined as parameters or entered directly into the input string at the appropriate dummy position for AVWI. As these variables have not been defined in the present version (20.VIII.1980), runs with fallows should not be attempted unless these revisions are implemented.

3.1.4. <u>Legume - wheat rotations in the fixed ley</u>. The differences between wheat and hay or pasture legumes that can be accounted for in the present model are as follows:

28	initial amount of seed sown	IGV
46	age of vegetation at seed fill initiation	ETF
46	age of vegetation for unrestricted seed fill	LTF
55	fraction of assimilate translocated to seed	TFVS.

The present version can account for legume pasture in an alternating ley system, but legume - wheat rotations within the cultivated area of the farm require some modification of the program. The amount of wheat seed sown must be differentiated from the amount of pasture seed sown, so IGVW must be split, say to IGVW and IGVL, and then IGVL will represent the amount of seed sown in the legume subsections. One to three subsections can be allocated
table 1 to legumes. Similarly, EWTF, LWTF and TFVSW would have to be subdivided and legume parameters added, say ELTF, LLTF and TFVSL. As the cultivated area in the fixed ley would not be grazed except in a drought year, the need to account for the different digestibility of the legume pasture could perhaps be neglected. Also, the criteria for sheep entry into the cultivated area and field allocation could be left as they are. If the legumes should be grazed
821/40 before the wheat, then the legume subsections (or 'fields') should be defined before the wheat subsections and <u>vice versa</u>.

It is more of a problem to simulate cutting of the legume hay at an appropriate time as the criteria are not the same as those

76 used for cutting wheat for hay. The option open in the present version, with small changes, is the following. The calls to the legume or wheat subsections can be differentiated by adjusting
23, table 1 the value of the parameter PS in the MACRO GROGV input string. At present, 1 indicates pasture and 0 indicates wheat. Say legume is indicated by setting PS to -1 in the appropriate calls of MACRO GROGV. The decision to cut wheat for hay can be defined as D2BHW
77 (instead of D2BH as at present) and the legume hay as D2BHL. Then D2BH will be chosen according to PS as it is set for each field.

D2BH = INSW (PS + 0.5, D2BHL, D2BHW)

D2BHL can be defined as:

D2BHL = HAY * INSW (GV + DV - 2000., 0., INSW (GV + DV - 6000., ...
INSW (GVP + DVP - NEWES * 12. * 14., 0., 1.), 1.)

174 implying that on the day when the decision must be taken (HAY = 1 in week 11, mid-March), hay will be cut from the legume fields if the total green and dry biomass is > 2t DM/ha and the amount of pasture in the pasture plots is enough to maintain the flock (NEWES) for at least 12 weeks consuming 14 kg DM/ewe/wk. In any event, hay will be cut if the standing biomass in the legume fields exceeds 6t DM/ha. This is a framework definition and if other values for the criteria are required, or if an optimizing routine is to be devised, then they can be adapted or added to the above procedure.

After the hay is cut and baled, the hay aftermath should be
757 available for grazing. This can be effected by ensuring that AINCRE
758 and/or AINCRW take on values equal to the number of legume paddocks. Preference would be given to weaners if there are any available at the time. It would be necessary to include this condition in the definition of AINCRE and AINCRW and it could be added as follows:

757 AINCRE = INTGRL(IAINE, INGWE-(INGWE + AINCRE - NOPPE) * HAYSW - ...
(INGWE + AINCRE - 4.) * HARV1 - etc.

758 AINCRW = INTGRL(IAINW, INGWW-(INGWW + AINCRW - NOPP) * HAYSW - ...
(INGWW + AINCRW - 4.) * HARV1 - etc.

The new variables NOPPE (number of open paddocks for pasturing ewes), NOPP (number of open paddocks for pasture) and HAYSW (switch which is normally zero, but equals 1 one week after hay harvest if hay was indeed harvested) are defined in the following procedure;

```
    PROCEDURE NOPPE, NOPP, HAYSW = HAYDAY (BLHY1, BLHY2, BLHY3,
                                                   BLHY4, NWNRS)
    HAYSW = 0.
    IF (YTIME .NE. HYTIM) GO TO 60
    BH1 = INSW(-BLHY1, 1., 0.)
    BH2 = INSW(-BLHY2, 1., 0.)
    BH3 = INSW(-BLHY3, 1., 0.)
    BH4 = INSW(-BLHY4, 1., 0.)
 60 CONTINUE
    IF (TIME .NE. HYTIM + DELT) GO TO 62
    NOPP = BH1 + BH2 + BH3 + BH4
    J = NOPP
    AFMATH = 0.
    CALL ARRAY (DVW1, DVW2, DVW3, DVW4, DVAM)
    CALL ARRAY (GVW1, GVW2, GVW3, GVW4, GVAM)
    DO 61 K = 1,J
 61 AFMATH = AFMATH + DVAM(K) + GVAM(K)
    AFMATH = AFMATH * FRW * J/4.
    NOPPE = INSW (NWNRS * 14. * (HWEEK - HYWEEK) * 2. - AFMATH, 0.,
                                                          NOPP)
    HAYSW = NOPP/(NOPP + NOT(NOPP))
 62 CONTINUE
    END PROCEDURE
    STORAGE DVAM(4), GVAM(4)
    TABLE DVAM(1-4) = 4*0., GVAM(1-4) = 4 * 0.
```

In the above procedure, BH1-4 are equal to one if the paddock has been cut for hay, and zero otherwise. If the aftermath (AFMATH) is more than double the needs of the weaners, then ewes are allowed to graze the aftermath too. The weaners' needs are set at 14 kg DM/wk for the period between hay and grain harvest date, after which all paddocks are opened to grazing (see definition of NOPPE). The criteria for determining a positive NOPPE can be changed or replaced by an optimizing routine if necessary.

There remains the need to correct the accounting procedure if
498/500 legumes replace wheat. The variable COST must be redefined as
follows. Instead of line 500,

CCULTW * FRW + ...)/DELT write -

(1-FRLEG)*(CCULTW*FRW+CHARW+CHARS+CHARH)+FRLEG*FRW*
(ACLEG-VALNIT))/DELT

FRLEG = NLEGP/4

PARAMETER NLEGP = number of legume paddocks (0-4)

PARAMETER ACLEG = annual cost of a legume pasture (IL/ha)

VALNIT = NITFIX * CFERT/0.21

PARAMETER NITFIX = nitrogen fixed by legume (kg N/ha)

Note: All money units should be changed from IL/ha to $/ha in a future model to eliminate inflationary effects.

3.2. <u>Sheep management</u>. The model is set up to deal with a breeding sheep flock that produces weaned lambs that can optionally be fat-
540 tened on pasture (RAISW). The breeding season and system (breed type, hormones given to increase fecundity), as well as the supplementary feeding regime, can be manipulated as discussed in sections 3 to 5 above. Grazing management includes deferment of grazing and paddock allocation. These aspects have been covered in sections 7 and 8. Two further systems that have been discussed in relation to sheep management practice at Migda are lamb-fattening on concentrated feed and opportunistic stocking of the pastures.

3.2.1. <u>Lamb-fattening on concentrated feed</u>. It will often be necessary to wean the lambs before they have reached a desirable market weight. In heavily stocked pastures it may be necessary to wean early as a matter of course. Whereas the weaning procedures have been elaborated (and could be improved), the alternative of fattening the animals on concentrate only has not. The simplest way to include concentrate fattening would be to zero the weaner pasture intake and replace it by concentrate:

230, 540, 479 PARAMETER RAISW = 1., to ensure that the weaners are not sold at weaning.

707/8 SUPPWC (concentrate supplement for weaners) must be redefined, say as SUPPWP (supplement for weaners on pasture), and then, SUPPWC = INSW (-FATLAM, MXDMIW, SUPPWP), where MXDMIW is the
712 maximum dry matter intake for ewes. It is now necessary to
710/11 zero the pasture intakes calculated for weaners (WDPI, WGPI). These need to be redefined as, say, WDPI1 and WGPI1. Then:

WDPI = INSW(-FATLAM, 0., WDPI1)

WGPI = INSW(-FATLAM, 0., WGPI1)

PARAMETER FATLM = 1., if weaners are to be fattened in feed lot, and 0. otherwise.

FATLAM = INSW(-WEAND, INSW(-SOLDW, 0., FATLM), 0.)

This procedure will fatten all the lambs after weaning but will return the hoggets to pasture after the other fattened weaners have been sold. In order to separate the pasture fatlambs from the future hoggets at weaning, it is necessary to define a new class of sheep, <u>viz</u>., fatlambs. Their number and weight would have to be monitored in separate integrals with their own routines. As this is a considerable development of the model, it should be elaborated with an optimizing routine that would consider seasonable lamb prices and sale weights that would maximize income. It should refine the costs to take into account capital investments in the feedlot as well as the labor costs involved in fattening the lambs. At this stage, these items should be added as a cost related to the number of weaners fattened and the fattening period.

CLFATL = INTGRL(0., FATLAM * NWNRS * DALICF)

PARAMETER DALICF = daily cost of labor and capital per fatlamb (IL/lamb/d).

490/502 CLFATL can then be added to COST in line 499, + CLFATL + ...

3.2.2. <u>Opportunistic lamb-raising on pasture</u>. Weaners can be bought after the season has begun, to utilize excess pasture if the
224, 509 farm is understocked. If the number of ewes (INEWE) is reduced to zero, then all the pasture can be used for raising bought weaners either on pasture with the standard options for management manipulation or with special legume pastures. It would be necessary to add the number of bought weaners, NBWNRS, to the weaners on pasture, assuming they have the same weight as the lambs that have grown on the farm, or that have a minimum live-weight if there are no home-grown lambs. When home-grown lambs are weaned and added to the bought weaners, it is necessary to calculate an average weight for all the weaners from that point on, unless the bought weaners are maintained in a separate class throughout. This again is a considerable expansion of the model and will not be developed at this stage. A routine that could handle the additional situation of whether there are or are not home-grown weaners, could be defined as follows:

```
      PROCEDURE NBWNRS, IWBWNR, BIWNRS = OPPORT (GVP,DVP,GVW1, GVW2,...
      GVW3,GVW4,DVW1, DVW2, DVW3, DVW4, RTIME, NEWES, HWEEK, WLAM)
      BIWNRS = 0.
      IF (RTIME .NE. BITIME) GO TO 67
      BIWNRS = 1.
      WPAST = GVP + DVP
      IF (NLEGP .EQ. 0.) GO TO 66
      CALL ARRAY (GVW1,GVW2,GVW3,GVW4,GVAM)
      CALL ARRAY (DVW1,DVW2,DVW3,DVW4,DVAM)
      J = NLEGP
      DO 65 K=1,J
   65 WPAST = WPAST + (GVAM(K) + DVAM(K)) * FRW * J/4.
   66 CONTINUE
      NBWNRS = AMAX1(0.,(WPAST - NEWES * (HWEEK-BITIME) * 21.) /
                      ((HWEEK - BITIME) * 14.))
      IWBWNR = AMAX1(WLAM, 15.)
   67 CONTINUE
      ENDPROCEDURE
      PARAMETER BITIME = 6.        (mid-February)
      PARAMETER NLEGP     (see section 3.1.3.)
      STORAGE DVAM(4), GVAM(4)
      TABLE DVAM(1-4) = 4*0., GVAM(1-4) = 4*0.
```

540/1 It is now necessary to effect changes in NWNRS, WWNR and COST as required:

```
540/1   NWNRS = INTGRL(INW,  ..... -NWNRS*PLOW+ NBWNRS * BIWNRS) / DELT)
703     WWNR = INTGRL(IWW,(BIWNRS * (IWBWNR+WWNR)/(NBWNRS+NWNRS)+     ...
               WEAN * (WLAM+WWNR)/(NLAMS+NWNRS)- WWNR * (BIWNRS + WEAN))/...
               DELT + WLWCH * 7. * (1. - PLOW) -      etc.
        COSTWN = BIWNRS * NBWNRS * IWBWNR * PRWNR * HIKE
```

This item has to be added to the farm. It is unlikely to be an expense that can be postponed until the end of the financial year, so it should be incurred when the weaners are bought and entered into the calculation of annual balance (ANBAL).

```
528     ANBAL = INTGRL (INBAL, GRINC-COSTWN-COST +     etc.
```

The parameter HIKE represents the ratio between the cost of the young bought weaner and the price of the full-grown weaner:

PARAMETER HIKE = 1.5 (i.e., young weaner is 50% more expensive per kg liveweight).

From here on the weaners will be subject to the management options previously defined for weaners. Parameter RAISW should be set to 1. However, the decision to give supplementary feed to the weaners
707, 231 can be controlled by D2SUPW. At a later stage it would be desirable to optimize the supplementary feeding and sale of the weaners endogenously.

4. PARAMETERS

4.1. Physical and Biological Parameters

4.1.1. Vegetative Growth and Seed Production

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION
DML1	0.001	/day	dry vegetation loss rate (weathering) - summer
DML2	0.05	/day	" " " " - beginning of growing season
DML3	0.01	/day	" " " " - end of growing season
DMLOM	0.15	/day	" " " " - on maturity (seed dispersal, etc.)
DRYR	0.10	/day	drying rate of green vegetation after end of growing season
EPTF	0.10	-	allocation factor - growth to early seed fill (pasture)
EWTF	0.30	-	" " - " " " " " (wheat)
FRGRM	0.50	-	fraction of pasture seed seed stock that germinates
LPTF	0.30	-	allocation factor - growth to late seed fill (pasture)
LWTF	0.90	-	" " - " " " " " (wheat)
MINSS	10.	kg/ha	minimum seed stock in soil (never 0)
MNRZ	30.	kg/ha	" ungrazable residual vegetation
MXGR	200.	kg/ha/day	maximum growth rate of vegetation
PRGR	0.1	/day	potential relative growth rate of vegetation
RGR	0.1	/day	" (redundant)
SENES	0.01	/day	drying rate of green phytomass
SLWK	0.1	/week	weekly seed loss rate due to predation by insects, birds
TFVSP	0.05	-	translocation fraction - veg to seed at maturity (pasture)
TFVSW	0.10	-	" " - " " " " " (wheat)

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION
4.1.2. Growth Control Factors			
EVBS	0.01	/day	evaporation constant for dry soil
M	200	-	transpiration : growth ratio, kg water/kg DM produced
MGCT	FT	kg/ha/time	measured or calculated growth curve over growing season
SMT	FT	-	growth regulation factor (redundant)
WTPG	20	mm	available water threshold for potential growth
4.1.3. Animal Characteristics			
AFTBF	1.5	-	after-birth factor (on lamb weight) for ewe weight loss at parturition
BIRWT	FT	kg/lamb/BF	birth weight of lambs, fn of BRDFR (=BF)
ECONLM	FT	/EWCON	reduction factor on birth weight, fn of EWCON
ECWT	FT	-	liveweight conversion efficiency, dig DM/kg LWG, fn of AGEW
EMORT	0.	/year	ewe mortality factor
EWCONB	FT	-	fertility factor at joining, fn of EWCON
EWCONS	FT	-	price reduction factor, fn of EWCON
KMNT	0.04	-	maintenance coefficient (kg DDM/kg metabolic body wt)
LAMRT	FT	/week	lamb mortality rate, fn of BRDFR
LGRT	FT	-	growth rate reduction factor, fn of LER
LMWIT	FT	kg/lamb/wk	potential lamb weight gain, fn of AGEW
LWRT	FT	-	reduction factor on price of weaners, fn of WWNR or WLAM
MXBRW	75.	kg/ewe	maximum breed weight (German Mutton Merino)
WOOLSH	2.5	kg/ewe/year	annual wool yield
ZERO	35.	kg/ewe	zero condition weight for adult sheep
4.1.4. Plant/Animal Interactions			
CXWT	FT	kg/sheep/day	maximum DM consumption of weaners, fn of AGEW
EGEF	0.004	ha/day	ewe grazing efficiency (S in Noy-Meir publications)
EWG	4.	week	earliest wheat-grazing week after emergence
GPTH	150.	kg/ha	green pasture threshold (redundant)
HQDPP	8.	week	high-quality dry pasture period

(contd.)

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION
NOGEF	8.	week	period of no grazing damage to wheat yield
SAFF	1.2	-	safety factor for deferment (GVP .GT. GVSAT)
SAFFE	4.	-	" " " " (GVP .LE. GVSAT)
TULP	0.25	kg/ewe/day	DM intake threshold for grazing deferment
WASTE	0.3	-	(=STWST) DM loss due to trampling
WPAST	2000.	kg/ha	minimum pasture for weaner grazing

4.1.5. Feed Parameters

DIGC	0.8	-	digestibility of concentrate feed
DIGCW	0.5	-	" " cotton gin waste
DIGC	0.75	-	" " green pasture
DIGH	0.6	-	" " hay
DIGS	0.4	-	" " straw
HDD	0.65	-	" " dry pasture - high value
LDD	0.55	-	" " " " - low value

4.2. Management Parameters

4.2.1. Land Management

FRPAST	0.5	-	fraction of area under pasture

4.2.2. Crop Management

B	0.5	-	fraction baled of post-harvest wheat biomass
D2GGW	0	-	(=GGWH) switch management decision to graze green wheat
FRHARW	0.9	-	fraction of wheat grain harvested
HLOSS	0.25	-	fraction of DM lost in haymaking
HOP	0	-	(D2BP in MACRO GROGV) cut wheat for hay option
IGVW	150	kg/ha	amount of wheat seed sown
MINGH	500	kg/ha	minimum amount of grain to harvest
SOP	1.	-	(D2BS in MACRO GROGV) bale wheat straw option
T	1000.	kg/ha	threshold stubble weight for baling
THGSR	0.05	-	threshold grain:straw ratio for wheat hay decision
W2BS	2.0	week	delay between grain harvest and straw baling
WFAIL	1000.	kg/ha	wheat failure threshold to allow ewes to graze
WHYS	7.	week	length of planned hay supplementation period
WSTS	16.	week	" " " straw supplementation period

4.2.3. Pasture Management

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION
DEFW	0	week	arbitrary deferred grazing period after emergence
DEFTHR	60.	kg/ha	green phytomass threshold for deferment (redundant)
IGVP	0	kg/ha	seed sown in pasture
AFERT	600.	kg/ha	amount of fertilizer applied (ammonium sulfate equivalent)

4.2.4. Animal Management

AWDP	12.	week	dry pasture reserve beyond NWYR
BREEDF	1.	lambs/ewe	potential breed fertility (German Mutton Merino)
CRASH	0.5	-	ewe condition for supplementary feeding (0-5)
CULLR	0.2	/ewe	culling rate
D2SUPE	0	-	switch management decision to give supplementary feed to ewes (0,1)
D2SUPL	0	-	" " " " give supplementary feed to lambs (0,1)
D2SUPW	1	-	" " " " give supplementary feed to weaners (0,1)
EARLW	0	-	" " " for early weaning (0,1)
ECSF	3.0	-	ewe condition threshold for steam up and flush
ECWN	0.8	-	" " " " weaning
FLUSH	0.25	-	extra feed allowance during breeding, lambing
FWAGE	30.	week	imposed weaning age
HORMT	1.	-	fertility factor due to hormone treatment
MINRW	25.	kg/lamb	minimum lamb weight for replacement
MINWGR	0.1	kg/head/day	" acceptable weaner growth rate on pasture
MXWSUP	1.	kg/head/day	maximum weaner supplementary feed ration (kg digestible conc. DM)
RAISW	0	-	switch option to raise weaners on pasture or to sell
SWW	50.	kg/head	sale weight of weaners
WLW	50.	kg/head	maximum weight of lambs at weaning

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION

4.2.5. Flag Days

EGWEEK	8	week	last possible germination date (=end Feb.)
EPWEEK	17	"	" " pasture maturity date (=beg. May)
EWWEEK	19	"	" " wheat maturity date (=mid May)
HWEEK	21	"	harvest date (=end May)
HYWEEK	11	"	date for decision to cut wheat for hay (=mid March)
JWEEK	32	"	joining date (=mid Aug.)
LDWEEK	9	"	latest grazing deferment date (=beg. March)
PWEEK	39	"	plowing date (=end Sept.)
SHEARW	22	"	shearing date (=beg. June)
SWEEK	40	"	start of simulation year (=beg. Oct.)

4.3. Economic Aspects

4.3.1. Accounting

BALE	0.117	IL/kg	cost of baling hay or straw
CAPINT	0.09	-	interest on capital (redundant)
CCULTW	1700.	IL/ha	cost of wheat cultivation (plow, fertilizers, seed, etc.)
CHORM	25.	IL/head	cost of fecundity hormone treatment
CLPE	30.	IL/head	cost of labor per ewe
DEPOSR	0.05	-	deposit interest rate
FHC	200.	IL/ha	fixed wheat harvest costs
FXPC	200.	IL/ha	fixed pasture costs (fence, water, fertilizers, etc.)
FXVPE	30.	IL/head	fixed veterinary costs per ewe
HPINC	0.3	-	relative hay price increase or decrease - season-dependent
LOANR	0.1	-	loan interest rate
RAKE	45.	IL/ha	cost of raking straw
SPINC	0.25	-	relative straw price increase or decrease - season-dependent
VHC	0.06	IL/kg	variable harvest costs

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION

4.3.2. Prices

CFERT	1.	IL/kg	price of fertilizer (ammonium sulfate units)
CPSEED	7.	"	" " pasture seed (medic, vetch, barley)
PRCONC	2.4	"	" " concentrate feed
PRCOTW	0.55	"	" " cotton gin waste
PRET	FT	"	" " ewe liveweight, fn of YTIME
PRGRN	1.8	"	" " grain
PRHT	FT	"	" " hay, fn of YTIME
PRLT	FT	"	" " lamb liveweight, fn of YTIME
PRST	FT	"	" " straw, fn of YTIME
PRWOOL	7.0	"	" " wool

4.4. Model Implementation

4.4.1 Initial Values

AVWI	0. *	mm	initial soil moisture reserve for transpiration
IAINE	0.	-	" no. of wheat paddocks open for grazing ewes
IAINW	0.	-	" " " " " " " " weaners
IAS	0.	week	" no. of weeks after germination
IBHY	0.	kg/ha	" amount of baled hay
IBRF	1.	-	" value of breeding factor
IBST	0.	kg/ha	" amount of baled straw
ICF	0.	kg/ha	accumulated amount of concentrate fed at start of run
ICW	0.	kg/ha	" " " cotton gin waste at start of run
IDI-4	0.	kg/ha	initial amount of dry phytomass in wheat subsections
IDEF	1.	-	" state of deferment invocation (0 = defer, 1 = do not)
IDMC	0.	kg/ha	" amount of DM already consumed, wheat & pasture
IDVP	1000.	kg/ha	" " " dry pasture
IFGW	0.	-	" fraction of wheat area open to grazing
IG1-4	0.	kg/ha	" green phytomass in wheat paddocks
IGP	0.	kg/ha	" " " " pasture paddocks
IGVP	0.	kg/ha	amount of pasture seed sown
IGVW	150.	kg/ha	" " wheat " "
IH1-4	0.	kg/ha	" " grain already harvested

(contd.)

PARAMETER	DEFAULT VALUE	UNITS	DEFINITION
IHST	0.	kg/ha	initial amount of hay in haystack
IMGR	0.	kg/ha	" measured biomass value (for derivative function)
INBAL	0.	IL/ha	" bank balance
INEWE	5.	head/ha	" sheep (ewe) density
INL	0.	head/ha	" no. of lambs (=INLAM)
INW	0.	head/ha	" " " weaners
IP1-4	0.	kg/ha	" primary production in wheat paddocks
IPP	0.	kg/ha	" " " " pasture paddocks
IPV	0.	kg/ha	" potential " , pasture
IREP	0.	head/ha	" no. of ewe replacements
IRZ1-4	30.	kg/ha	" residual ungrazable phytomass - wheat
IRZP	30.	kg/ha	" " " " - pasture
IS1-4	0.	kg/ha	" standing seed in wheat paddocks
ISP	100.	kg/ha	" seed stock or standing seed in pasture
ISST	0.	kg/ha	" amount of straw in straw stack
IWEW	55.	kg/head	" weight of ewes
IWL	0.	kg/head	" " " lambs (=IWLAM)
IWW	0.	kg/head	" " " weaners

* Note: most zero default initial values are defined as variables so that it is possible to make exploratory runs that begin at any time during the year when the "initial" value may be non-zero.

4.4.2. Output Options

CHESHB	1.	-	1 = print annual account summary, 0 = do not
LBL	1.	-	1 = print label for annual account summary, 0 = do not
POLICY	1.	-	identification number of management policy
SPOUT	1.	-	1 = call output on flag days, 0 = do not

4.4.3. Multiple-Year Runs

The simplest way to implement multiple-year runs is to use the statement END CONTINUE instead of END. It is then necessary to place the new measured growth curve data (and any desired change in management policy option selectors) after END CONTINUE. This can be repeated for any number of years. The end of the last simulation year should be indicated by a simple END statement. It may be necessary to replace the

TERMINAL statement by a NOSORT followed by appropriate directions. The multiple-year run would then be set up as follows:

```
     IF(YTIME .NE. 52.) GO TO 1000
     -
     -
     -
1000 CONTINUE
     SORT
     END CONTINUE
     FUNCTION MGCT = ....
     -
     -
     FUNCTION SMT = ....
     END CONTINUE
     -
     -
     -
     END CONTINUE
     -
     -
     -
     END
     STOP
      ENDJOB
```

5. FUNCTION TABLES (DEFAULT VALUES)

The function tables are listed here in alphabetical order. Intermediate values are calculated by linear interpolation by CSMP.

5.1. FUNCTION BIRWT

Birth-weight of lambs (kg/head) as a function of litter size, BRDFR (lambs/ewe).

BRDFR	0.	0.5	2.0	3.0
BIRWT	6.	6.	3.	2.5

5.2. FUNCTION CXWT

Maximum dry matter consumption of weaners (kg DM/head/d) as a function of age of weaner, AGEW (wk).

AGEW	0.0	4.0	5.0	6.0	10.0	12.0	16.0	19.0	22.0	40.0	52.0
CXWT	0.0	0.0	0.3	0.5	0.72	0.74	1.0	1.06	1.2	1.5	1.7

5.3. FUNCTION ECONLM

Reduction factor (dimensionless) on lamb birth-weight as a function of ewe condition, EWCON (dimensionless)

EWCON	0.0	1.0	1.01	2.5	5.0
ECONLM	0.0	0.0	0.5	1.0	1.0

5.4. FUNCTION ECWT

Conversion efficiency of digestible dry matter above maintenance requirement of liveweight (kg liveweight gain/d/kg DDM) in weaners as a function of weaner liveweight (WWNR).

WWNR	0.0	2.0	42.0	55.0
ECWT	0.77	0.77	0.55	0.5

5.5. FUNCTION EWCONB

Reduction factor (dimensionless) on ewe conception rate as a function of ewe condition (EWCON).

EWCON	0.0	1.0	2.5	4.0	5.0
EWCONB	0.0	0.0	1.0	1.0	0.5

5.6. FUNCTION EWCONS

Reduction factor (dimensionless) on sale price of ewe as a function of ewe condition (EWCON).

EWCON	0.0	1.0	2.0	3.0	5.0
EWCONS	0.0	0.0	0.67	1.0	1.0

5.7. FUNCTION LAMRT

Lamb mortality reduction factor (dimensionless) as a function of litter size (BRDFR).

BRDFR	0.0	0.5	0.8	1.0	1.5	2.0	3.0
LAMRT	1.0	1.0	0.98	0.95	0.9	0.85	0.7

5.8. FUNCTION LGRT

Lamb growth rate reduction factor (dimensionless) as a function of number of lambs suckled per ewe (LER = lamb/ewe ratio).

LER	0.0	0.5	1.0	2.0	3.0
LGRT	1.0	1.0	1.0	0.8	0.7

5.9. FUNCTION LMWIT

Potential lamb daily weight gain (kg/head/d) as a function of age of lamb (AGEW).

AGEW	0.0	4.0	12.0	20.	40.	52.
LMWIT	0.25	0.35	0.35	0.2	0.1	0.1

5.10. FUNCTION LWRT

Price reduction factor on underweight lambs (dimensionless) as a function of lamb liveweight (WLAM).

WLAM	0.0	5.0	10.0	50.0
LWRT	0.0	0.0	1.0	1.0

5.11. FUNCTION MGCT

Measured growth curve (kg DM/ha) as a function of simulation year time (YTIME, in weeks).

YTIME	0.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
MGCT	0.	0.	20.	40.	80.	150.	250.	400.	650.	1000.	1500.	1900.

YTIME	18.	19.	20.	21.	22.	23.	24.	25.	26.	52.
MGCT	2400.	2500.	2600.	2800.	3000.	3200.	3300.	3400.	3500.	3500.

Source: Migda, Field 13, NPK, 1976/77. Field data recalculated to obtain weekly values.

5.12. FUNCTION PRET

Seasonally dependent ewe price (IL/kg liveweight) as a function of simulation year time (YTIME, in weeks).

YTIME	0.	52.
PRET	15.	15.

Note: Dummy values based on 1977 prices. All prices must be updated to the year being simulated unless constant values are assumed.

5.13. FUNCTION PRHT

Seasonally dependent hay price (IL/kg d. wt.) as a function of simulation year time (YTIME, in weeks).

YTIME	0.	52.
PRHT	0.90	0.90

Note: see 5.12.

5.14. FUNCTION PRLT

Seasonally dependent lamb liveweight prices (IL/kg) as a function of simulation year time (YTIME, in weeks).

YTIME	0.	52.
PRLT	23.	23.

Note: see 5.12.

5.15. FUNCTION PRST

Seasonally dependent straw prices (IL/kg d. wt.) as a function of simulation year time (YTIME, in weeks).

(contd.)

YTIME	0.	52.
PRST	0.45	0.45

Note: see 5.12.

5.16. FUNCTION SMT

Reduction factor on potential growth (dimensionless) as a function of simulation year time (YTIME, in weeks). Calculated from undisturbed growth curves for the particular simulation year.

YTIME	0.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
SMT	0.	0.	.1	.95	.92	.76	.69	.65	.56	.43	.23	.24	.09	.09

YTIME	20.	21.	22.	23.	24.	25.	26.	52.
SMT	.17	.16	.12	.06	.03	.06	0.	0.

Note: see 5.11 (source).

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APPENDICES

Appendix I

THE MIGDA SYSTEM MODEL

The model is written in CSMP III. Program line numbers referred to in the text appear on the right-hand side of the program listing

```
00000001 TITLE MIGDA MANAGEMENT MODEL (JANUARY 1978)
00000002
00000003 *  DELT = WEEK , AREA UNIT = HECTARE , WEIGHT UNIT = KILOGRAM
00000004
00000005
00000006 SYSTEM  NPOINT = 2000
00000007 STORAGE SV(8),MMV(24),YM(24),IST(20),ZSUPP(4),ZUPD(2)
00000008 STORAGE WGRZW(4),WW(4),RZW(4),GVWH(4),DVWH(4)
00000009 FIXED  I,N,NYEAR,J,K,K1,ISEL
00000010
00000011 TABLE    YM(1-20)=20*0.
00000012 * IS (FOR CNPKM 75/76) = 50./FRGERM=100.
00000013 TABLE  ZSUPP(1-4)=4*0.,  ZUPD(1-2)=2*0.
00000014 TABLE WGRZW(1-4) = (4*0.), WW(1-4)  = (4*0.), GVWH(1-4) = (4*0.), ...
00000015       DVWH(1-4) = (4*0.), RZW(1-4) = (4*0.)
00000016
00000017 *
00000018 *====================================================  SECTION  1  ====
00000019 *
00000020 *  CALCULATE PASTURE + WHEAT GROWTH
00000021 MACRO GV,DV,GRV,DRGV,ING,TRG,LOSS,IND,GRAIN,GHARV,BLST,BLHY, P,RZ   ...
00000022   =GROGV(IGV,FRG,ETIME,EIW,WIW,     FR,ETF,LTF,    TFVS,GRE,GRW,PLOW,...
00000023          HARV,D2BP,D2BS,IS,IG,ID,IP,IRZ,IH,PS)
00000024 * NOTE - MORE INPUT VARIABLES PLACED BEFORE MACRO CALLS IN PROGRAM
00000025
00000026 ****GREEN VEGETATIVE BIOMASS****
00000027
00000028 GV = INTGRL(IG,FRG*GERM*(IGV+GRAIN)/DELT+NGRV-HARV1*(GV/DELT+NGRV))
00000029 NGRV = GRV-DRGV-ING-AMAX1(0.,HAY*(GV-500.-DRGV-ING)*D2BH/DELT)
00000030
00000031 * GRV CALCULATED FROM  DATA AND CORRECTED FOR UNUSED WATER RESERVE
00000032 * (AVW) BACK CALCULATED FROM MEASURED GROWTH RATE (MGR) AND ACTUAL
00000033 * GROWTH RATE (GRV)
00000034
00000035 GRV = INSW(GV-1900.,EXGR*GV,LINGR)*DVS*(1.-TRG)
00000036 EXGR = AMAX1(WEGR,LIMIT(0.,1.,AVW/WTPG)*PRGR*D7)
00000037 LINGR = MXGR*D7*AMAX1(SM,LIMIT(0.,1.,AVW/WTPG))
00000038 AVW = INTGRL(AVWI,(MGR-GRV)*M/1.E4-AVW*EVBS*D7*(1.+ ASMWK/12.))
00000039 MGR = DERIV(IMGR,AFGEN(MGCT,YTIME+0.5*DELT))
00000040
00000041 P = INTGRL(IP,GRV/(1.-TRG)*(1.-NWYR)-NWYR*P/DELT)
00000042 DVS = INSW(GV-1.,0.,INSW(ASMWK-25.,INSW(YTIME-ETIME,1.,0.),0.))
00000043 DRGV=(GV/DELT-ING)*7.*AMAX1(SENESC,DRYR-SM*DRYR*10.)+HARV1*GV*(1.-TFVS)
00000044 ING = GRZN*AMIN1(GV/DELT,(EGPI*EIW*NEWES*7.+WGPI*WIW*NWNRS*7.)/FR1)
00000045 FR1 = INSW(-PS,FRPAST,(FR+NOT(FR))/4.)
00000046 TRG = INSW(YTIME-23.,INSW(ASMWK-13.,0.,INSW(ASMWK-15.,ETF,LTF)),LTF)
00000047
00000048 *RESIDUAL GREEN (STEM BIOMASS)
00000049 RZ = INTGRL(IRZ,IGVR-(IGVR+(RZ-MNRZ)/DELT)*GERM-RZ*PLOW/DELT)
00000050 IGVR = INSW(-TRG,120./1000.*GRV,0.)
00000051
00000052 *SEED PRODUCTION AND HARVEST
00000053 GRAIN = INTGRL(IS,GRGR-GRHAR-SDL-GSEED-(GRAIN/DELT-SDL)*(PLOW+1.-G))
00000054 GSEED=GERM*AMAX1(MINSS,GRAIN)*(1.-FRG)/DELT+(GRGR+GRAIN/DELT)*D2BH
00000055 GRGR = GRV*TRG/(1.-TRG)*INSW(GRAIN-GV-DV,1.,0.)*G+TFVS*GV*EGS*G/DELT
00000056 G = 1.-AMIN1(1.,GRE+GRW)
00000057 GRHAR = (1.-AMIN1(1.,GRE+GRW))*HARV*FRHARW*GRAIN/DELT
00000058 SDL = INSW(YTIME-(HTIM+1.),0.,GRAIN*SLWK)
00000059 GHARV = INTGRL(IH,GRHAR-GHARV*NWYR/DELT)
00000060 GRZN = INSW(EIW+WIW-1.,0.,1.)
00000061
00000062
00000063
00000064 ****DRY VEGETATIVE BIOMASS****
00000065
00000066 DV = INTGRL(ID,NDVR*(1.-PLOW)+((1.-G+D2BH )*GRAIN-DV*PLOW)/DELT)
00000067 NDVR = DRGV-LOSS-IND-BLST- AMAX1(0.,HAY*(DV-1000.)*D2BH/DELT)
00000068 LOSS = (DV/DELT-IND)*LOSS1*7.+INSW(DV/DELT-IND*(1.+WASTE),0.,WASTE*IND)
00000069 IND = GRZN*AMIN1(DV/DELT,(EDPI*EIW*NEWES*7.+WDPI*WIW*NWNRS*7.)/FR1)
00000070
00000071
00000072
00000073 *BALE STRAW AND HAY
00000074
00000075 BLST=D2BS*DV*B*BAYL
00000076 BLHY = D2BH*HAY*(AMAX1(0.,GV-500.)+AMAX1(0.,DV-1000.))/DELT
```

```
D2BH = D2BP*INSW(-HAY,INSW(GV+DV-2000.,0.,INSW(GV-1000.,0.,AUX2)),0.)
 AUX2 = INSW(GRAIN/((DV+GV)+NOT(GV+DV))-THGSR,1.,0.)*TUDRY
ENDMAC


*
*==================================================== SECTION  2  ====
*

* ====    MACRO(PADOK)  REPLACED  BY  SUBROUTINE(PADOK)  ====

*
*==================================================== SECTION  3  ====
*

MACRO ACT = MACT(XTIM)
ACT = FCNSW(XTIM-YTIME,0.,1.,0.)
ENDMAC


MACRO CTIME = CT(WEEK)
CTIME = INSW(WEEK-SWEEK,52.-(SWEEK-WEEK),WEEK-SWEEK)
ENDMAC


MACRO DONE,XTIM1= CDX(AKT,MT)
DONE = INTGRL(0.,(AKT-DONE*MT)/DELT)
XTIM1 = INTGRL(52.,(AKT*(YTIME-52.)-(XTIM1-52.)*MT)/DELT)
ENDMAC


*
*==================================================== SECTION  4  ====
*

****FUNCTION TABLES****


* PRLT = PRICE OF LAMBS,LWRT = PRICE REDUCTION LOW LAMB WT, PRET = PRICE
* EWCONS = PRICE RED LOW EWE COND,PRST = PRICE OF STRAW, SYRT = STRAW YE
* BOOST PRICE IN BAD YR, EWCONB = EWE CONDITION(BREEDING),LAMRT = LAMB
* MORTALITY RATE,BIRWT = BIRTH FNOF BRDFR,EWCONS = EWE CONDITION (SALE)
* LGRT = LAMB GROWTH RATE                        SMT = SOIL MOISTURE
* CXWT = MAX DM CONSUMPTION OF WEANERS FN OF AGE OF WEANER(AGEW)
* LMWIT = POTENTIAL  LAMB WT INC/DAY  -  FN OF AGEW
* ECWT = CONVERSION EFF TO LW (WEANERS),FN OF WEIGHT(WWNR)

FUNCTION  MONTT = 0.,1.,  4.1,1.,  4.9,2.,  8.1,2., 8.9,3., 13.1,3., ...
       13.9,4.,  17.1,4.,  17.9,5.,  22.1,5.,  22.9,6.,  26.1,6.,  ...
       26.9,7.,  30.1,7.,  30.9,8.,  35.1,8.,  35.9,9.,  39.1,9.,  ...
       39.9,10.,  44.1,10.,  44.9,11.,  48.1,11.,  48.9,12.,  52.1,12.

FUNCTION PRLT= 0.,23.,  52.,23.
FUNCTION LWRT = 0.,0.,  5.,0.,  10.,1.,  50.,1.
FUNCTION PRET = 0.,15.,     52.,15.
FUNCTION PRST = 0.,0.45,  52.,0.45
FUNCTION PRHT = 0.,0.90,  52.,0.90
FUNCTION EWCONB = 0.,0.,  1.,0.,  2.5 ,1.,  4.,1.,  5.,0.5
FUNCTION EWCONS = 0.,0.,  1.,0.,  2.,0.67,  3.,1.,  5.,1.
FUNCTION  LAMRT = 0.,1.,              ...
                 0.5,1.,  0.8,0.98,  1.,0.95,  1.5,0.9,  2.0,0.85, ...
                 3.0,0.7
FUNCTION BIRWT = 0.,6.,  0.5,6.,  2.,3.,  3.,2.5
FUNCTION LGRT = 0.,1.,  0.5,1.,  1.,1.,  2.,0.8,  3.,0.7
FUNCTION SMT   =0.,0., 7.,0., 8.,.1,  9.,0.95,  10.,0.92,  11.,0.76,...
                 12.,0.69,  13.,0.65,  14.,0.56,  15.,0.48,           ...
                 16.,0.23,  17.,0.24,  18.,0.09,  19.,0.09,           ...
                 20.,0.17,  21.,0.16,  22.,0.12,  23.,0.06,           ...
                        24.,0.03,  25.,0.06,  26.,0.,  52.,0.
FUNCTION  MGCT = 0.,0.,  7.,0.,  8.,20.,  9.,40.,  10.,80.,  ...
      11.,150.,  12.,250.,  13.,400.,  14.,650.,  15.,1000.,  ...
      16.,1500.,  17.,1900.,  18.,2400.,  19.,2500.,  20.,2600.,  ...
      21.,2900.,  22.,3000.,  23.,3200.,  24.,3300.,  25.,3400.,  ...
      26.,3500.,  52.,3500.
FUNCTION CXWT = 0.,0.,  4.,0.,  5.,0.3, 6.,0.5,   10.,0.72,  12., ...
                0.74,  16.,1.  19.,1.06,  22.,1.2,  40.,1.5,  52.,1.7
FUNCTION  LMWIT = 0.,.25, 4.,.35, 12.,.35, 20.,.2, 40.,.1, 52.,.1
FUNCTION ECWT = 0.,.77,  2.,0.77,  42.,0.55,  55.,0.5
FUNCTION ECONLM = 0.,0.,  1.,0.,  1.01,0.5,  2.5,1.,  5.,1.
```

```
INITIAL

*
*=====================================================  SECTION  5  ====
*
****SWITCH PARAMETERS ****          ***1-7 JANUARY = WEEK 1***
* SWEEK = STARTING ,JWEEK = JOINING, LWEEK = LAMBING,
* EGWEEK = END GERMINATION,  HWEEK = HARVEST,  PWEEK = PLOW,  SHEARW = S
* EPWEEK = PASTURE MATURITY,  EWWEEK = WHEAT MATURITY, LDWEEK = LAST DEF
*WEEK, HYWEEK = D2 CUT WHEAT FOR HAY. YSEL=YEAR SELECTOR
* BSWEEK=BALE STRAW WEEK,  W2BS=WEEKS AFTER HARVEST TO BALE STRAW
*
* KEY (WEEK=DATE)  1=1JAN,  6=5FEB,  10=5MAR,  14=2APR,  19=7MAY,
* KEY              23=4JUN,  27=2JUL,  32=6AUG,  36=3SEP,  40=1OCT,
* KEY              45=5NOV,  49=3DEC,  52=24DEC,  53=31DEC
*
PARAM  SWEEK = 40.,  JWEEK = 32.,  EGWEEK = 8.,  HWEEK = 21., HYWEEK=11.
PARAM  PWEEK = 39.,  SHEARW = 22.,  EPWEEK = 17., EWWEEK = 19.,LDWEEK=9.
LWEEK=INSW(52.-(JWEEK+21.),(JWEEK+21.)-52.,JWEEK+21.)
      BSWEEK=HWEEK+W2BS
PARAM YSEL=0.,      W2BS=2.

D7 = DELT*7.

****ECONOMIC PARAMETERS****
* INBAL = INITIAL BANK BALANCE, LOANR = LOAN INTEREST, DEPOSR = DEPOSIT
* PRWOOL,PRGRN = PRICE WOOL,GRAIN,  (PRLAM,PREWE,PRSTR = VARIABLES),
* PRSE,PRSL = PRICE OF SUPPLEMENTARY FEED FOR EWES,LAMBS, FXPC = FIXED
* CHOR = COST OF HORMONES/EWE (IL)
* PASTURE COST, CFERT = COST FERTILIZER, AFERT = AMT FERT
* CLPE = COST LABOUR/EWE, FXVPE = FIXED VET COSTS/EWE,CCULTW = COST CULT
* VHC = VARIABLE HARVEST COST/KG, FHC = FIXED HARVEST COST

PARAM  INBAL  = 0.,  LOANR = 0.1,  DEPOSR = .05, CAPINT = 0.09, ...
       CPSEED=7.,PRWOOL =   7., PRCONC = 2.4, PRCOTW = 0.55
PARAM PRGRN = 1.8, FXPC = 200., CFERT =1., AFERT = 600., CHORM = 25.
PARAM FXVPE = 30., CCULTW = 1700., VHC = 0.06, FHC = 200., RAKE = 45.
PARAM BALE = 0.117
* CLPE = 3.*5000.*2./1000.
PARAM CLPE=30.

****ANIMAL MANAGEMENT PARAMETERS****
* INEWE= INITIAL NO. EWES/HA, INLAM = INITIAL NO. LAMBS, CULLR = CULLING
* BREEDF = BREEDING FERTILITY(1-2), HORMT = HORMONE TREAT, INEWE = INIT
* ECWN, ECSF = EWE COND THRESHOLD FOR WEANING, STEAM AND FLUSH
* CRASH=EWE CONDITION FOR SUPPLEMENTARY MAINTENANCE FEEDING
* WLW= WEIGHT OF LAMBS AT WEANING
* FWAGE= FORCED WEANING AGE (WEEKS)
* MXBRW = MAX WT OF BREED, ZERO = ZERO CONDITION WT OF BREED
* HDD,LDD = HIGH, LOW VALUES FOR DRY PASTYRE DIGESTIBILITY
* HQDPP= HIGH QUALITY DRY PASTURE PERID (WEEKS)
* THRINT,THRINP = THRES INTAKE BEFORE MAINT FEEDING,FLUSHING FEEDING,
* PREPP = FLUSH PERIOD, DIGG,DIGD,DIGSL,DIGSE = DIGESTIBILITY GREEN PAST
* DRY PAST,SUPPL FEEDLAMBS,EWES.FLUSH = FRACTION INCREASE FEED,
* KMNT = MAINTENANCE COEFF, MXEINT = MAX EWE INTAKE
* EARLW = EARLY WEANING SYSTEM, RAISEW = RAISE WEANER SYSTEM
* THEW = THRESHOLD WEEK FOR EARLY WEANING
* SWW = SALE WT WEANERS FRWEAN = FRACTION WEANED,EMORT = EWE MOR RATE/YE
* D2SUPE,D2SUPL,D2SUPW,D2GGW,D2GDW = DECIDE TO SUPPL EWES,LAMBS,WEANERS,
* GREEN WHEAT,DRY WHEAT, WOOLSH = WOOL YIELD PER SHEEP,GGWH = GRAZE GREE
* WHEAT. IWLAM = INITIAL WT LAMB,DIGDME = DIG DM FOR EWE MAINT
* MINRW = MINIMUM LAMB WT FOR REPLACEMENT, AFTBF = AFTER BIRTH FACTOR, D
* GVP THRESHOLD FOR DEFERMENT, MINWGR = MINIMUM WEANER DAILY GROWTH RATE
* EGEF = EWE GRAZING EFFICIENCY IN HA/DAY, MXWSUP = MAX WEANER SUPPL
* (KG DIG CONC)

PARAM INEWE =5., INLAM = 0., CULLR = 0.2, BREEDF = 1., HORMT = 1.
PARAM IWEW  = 55., MXBRW = 75., ZERO = 35., ECWN = 0.8, ECSF = 3.0
PARAM DIGC = 0.75,  HDD=.65,  LDD=.55,  CRASH=0.5
PARAM WLW=50.,  FWAGE=30.,  HQDPP=8.
PARAM             DIGS = 0.4, DIGH = 0.6, DIGCW = 0.5
PARAM DIGC  = 0.8,               FLUSH = 0.25, KMNT = 0.04
PARAM EARLW = 0., RAISW = 0., SWW = 50., EMORT = 0.,D2SUPE = 0.
PARAM D2SUPL = 0., D2SUPW = 1., D2GGW = 0., WOOLSH = 2.5, GGWH = 0.
PARAM MINRW = 25., AFTBF = 1.5, DEFTHR = 60.
PARAM MINWGR = 0.1, EGEF = 0.004, MXWSUP = 1.
      CULLS = INEWE*CULLR
```

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****PASTURE AND WHEAT PARAMETERS****
* FRPAST,FRWHT = FRACTION OF AREA PASTURE,WHEAT, GPTH = GREEN PASTURE TH
* IGVP1,IDVP,IGVW = INITIAL GREEN,DRY,PAST,WHEAT VEG BIOMASS DUE TO SOWI
* RGR =POTENTIAL RELATIVE GROWTH RATE (/DAY)
* MINSS=MINIMUM SEED STOCK (KG/HA)
* WPAST=MINIMUM PASTURE FOR WEANER GRAZING (KG/HA)
* AWDP=ADDITIONAL WEEKS OF DRY PASTURE RESEVE NEEDED BEYOND NWYR (WEEKS)
* WSTS=WEEKS OF POTENTIAL STRAW FEEDING (WEEKS)
* WHYS=WEEKS OF POTENTIAL HAY FEEDING (WEEKS)
* MINGH=MINIMUM AMOUNT OF GRAIN FOR HARVESTING (KG/HA)
* HOP=HAY OPTION FOR WHEAT
* SOP=STRAW BALING OPTION(WHEAT OR PASTURE)
* STWST = STRAW WASTAGE FACTOR DUE TO GRAZING
* EWTF,LWTF,EPTF,LPTB = EARLY,LATE PHASE,WHEAT,PAST,TRANSLOCATION FRACTI
* DM TO SEED, TFVSW, TFVSP = TRANSLOC VEG BIOMASS TO SEED FRACTION WHEAT
* SENES = SENESCENCE RATEOF GREEN VEG,DRYR = DRYING RATE OF VEGETATION A
* EGS, FRHARW = FRACTION WHEAT GRAIN HARVESTED,FRB  = FRACTION DRY WHEAT
*FOR STRAW, THB   = THRESHHOLD STUBBLE WT FOR BALING, SLWK = PASTURE SEE
* LOSS RATE/WEEK,MINSS=MINIMUM SEED STOCK IN PASTURE
* HLOSS = DM LOSS IN HAYMAKING, THGSR = THRESHOLD GRAIN/STRAW RATIO,
* WFAIL=CRITERION FOR WHEAT FAILURE AT BEGINNING OF APRIL(THRESHOLD DPW+
* MXGR = MAX GROWTH RATE OF VEGETATION, RGR1 =  MAX REL GROWTH RATE.
* DMLOM = DM LOSS ON MATURITY OF VEGETATION, MNRZ = MIN RESIDUAL GREEN
* OR DRY VEGETATION (KGS/HA)
* MXSS = MAX STRAW STACK  CAPACITY, MXHST = MAX HAY STACK CAPACITY,
* TULP = TOO LITTLE PASTURE (KGS DM INTAKE/EWE/DAY)-THRESHOLD FOR DEFERM
*FRGERM = FRACTION OF PASTURE SEEDS THAT GERMINATE, IS = INITIAL AMT OF
* SEED IN PASTURE. SAFF,SAFFE = SAFETY FACTORS FOR DEFERMENT,
* IGP = INITIAL GREEN VEG IN PASTURE (KG/HA)
* DEFW = WEEKS OF DEFERMENT AFTER GERMINATION.
* NOGEF = NUMBER OF WEEKS AFTER GERMINATION THAT GRAZING DOES NOT ...
* AFFECT GRAIN YIELD
* EWG = EARLIEST WHEAT GRAZING WEEK AFTER GERMINATION
* DML1,DML2,DML3=DRY MATTER LOSS RATE SUMMER,BEGIN+END OF GROWING SEASON
* WASTE= WASTAGE FACTOR - DRY MATTER LOSS DUE TO TRAMPLING

PARAM FRPAST = 0.5, GPTH = 150., IGVP  = 0., IDVP =1000., IGVW = 50.
PARAM  RGR  = 0.1,  MINSS = 10.,WPAST=2000.,AWDP=12.,WSTS=16.,    ...
       WHYS=7.,MINGH=500.,  HOP=0.,    SOP=1.,    STWST=1.
        FRW = 1. -FRPAST
PARAM EWTF = 0.3, LWTF = 0.9, EPTF = 0.1, LPTF = 0.3, SENES = 0.01
PARAM DRYR = 0.10, TFVSW = 0.1, TFVSP = 0.05, FRHARW = 0.9,  B=0.5
PARAM T      = 1000., SLWK = 0.1, HLOSS = 0.25, THGSR = 0.05, WFAIL=1000.
PARAM MXGR = 200.,                DMLOM = 0.15, MNRZ = 30., TULP = 0.25
PARAM FRGERM = 0.5,               IGP = 0.,SAFF = 1.2, DEFW = 0., SAFFE=4.
PARAM   NOGEF = 8.,  EWG = 4., DML1=0.001, DML2=0.05, DML3=0.01
PARAM WASTE=0.3

* FRR = FRACTION WHEAT STRAW REMAINING AFTER BALING
* EWSREQ = EWE REQ FOR WHEAT STUBBLE IN SUMMER
R = 1-B
E = INEWE*10.5*(PTIM-ST)/(1.+WASTE)
*  B = FRB
*  R = FRR
*  E = EWSREQ
*  T = THB

*MAXIMUM HAY,STRAW STORAGE/HEAD
MXSST= 7.*1.*INEWE*WSTS
MXHST = 7.*1.5*INEWE*WHYS


* PARAMETERS AND FUNCTIONS FOR GRV CALCULATION

* WTPG = AVAIL WATER THRESHOLD FOR POTENTIAL GROWTH (MM)
* EVBS = EVAPORATION CONSTANT FOR BARE SOIL (FRACTION)
* PRGR = POTENTIAL RELATIVE GROWTH RATE
* M = TRANSPIRATION/DM  RATIO (KG TRANSP WATER/KG DM GROWN)
* MGCT = MEASURED GROWTH CURVE TABLE
* FUNCTION  MGCT = 0.,0., ......,52.,0.

PARAM  WTPG = 20.,  EVBS = 0.01,  AVWI = 0.,  IMGR = 0.,  PRGR = 0.1
PARAM  M = 200.

****   INTEGRAL  INITIATION  - NB  WHEN START TIME NE 0.
* INPUTS TO MACRO GROGV FOLLOW  -
* ISP,IS1-4 = INIT SEED STOCK OR STANDING SEED, PASTURE,WHEAT
* IGP,IG1-4 = INIT GREEN PHYTOMASS, PASTURE,WHEAT
* IDVP,ID1-4 = INIT DRY PHYTOMASS, PASTURE, WHEAT
* IPP,IP1-4 = INITPRIMARY PRODUCTION   PASTURE, WHEAT
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* IRZP,IRZ1-4 = INITRESIDUAL UNGRAZABLE PHYTOMASS
* IH1-4 = INIT GRAIN YIELD HARVESTED
* PS    = PASTURE (1)  OR  WHEAT (0)
*
* IAS = INIT ACCUMUL  SM  WEEK
* IPV = INIT POTENTIAL  PRODUCTION
* INBAL = INIT BANK BALNCE
* INEWE,INL,INW,IREP = INIT NUMBER EWES,LAMBS,WEANERS,REPLACEMENTS
* IWEW,IWL,IWW = INIT WEIGHT EWES,LAMBS,WEANERS
* IBRF = INIT BREEDING FACTOR
* IAINE,IAINW = INIT ACCUMUL INCREM OF WHEAT FOR EWES, WEANERS
* IFGW = INIT FRACTION OF GRAZED WHEAT
* IDEF = INIT DEFERMENT OF GRAZING ON PASTURE (1=NODEFER,0=DEFER)
* ISST,IHST,IBST,IBHY = INIT STRAW-,HAYSTACK,-STRAW,HAY BALED
* ICF,ICW = INIT CONC FEED, COTTON GIN WASTE
* IDMC = INIT DRY MATTER CONSUMED FROM WHEAT AND PASTURE
*****    REMEMBER SET TIME = NEW STARTING WEEK
PARAM  ISP = 100.,    IS1=0.,      IS2=0.,      IS3=0.,     IS4=0.
PARAM  IGP=0.,      IG1=0.,      IG2=0.,      IG3=0.,     IG4=0.
PARAM  IDVP=1000.,   ID1=0.,      ID2=0.,      ID3=0.,     ID4=0.
PARAM  IPP=0.,      IP1=0.,      IP2=0.,      IP3=0.,     IP4=0.
PARAM  IRZP=30.,    IRZ1=30.,    IRZ2=30.,    IRZ3=30.,   IRZ4=30.
PARAM               IH1=0.,      IH2=0.,      IH3=0.,     IH4=0.
***************************
PARAM  IAS=0.,      IPV=0.,      INBAL=0.
PARAM  IAINE=0.,     IAINW=0., IFGW=0.,     IDEF=1.
PARAM  INEWE=5.,    INL=0.,      INW=0.,      IREP=0.
PARAM  IWEW=55.,    IWL=0.,     IWW=0.,       IBRF=1.
PARAM  ISST=0.,      IHST=0.,     IBST=0.,     IBHY=0.
PARAM  ICF=0.,       ICW=0.,     IDMC=0.

* MACRO CALLS CTIME = CT(WEEK) TO CONVERT DATE TO DAY IN RUN
LTIM = CT(LWEEK)
JTIM = CT(JWEEK)
LGTIM =  CT(EGWEEK)
EPTIM = CT(EPWEEK)
EWTIM = CT(EWWEEK)
HTIM = CT(HWEEK)
PTIM = CT(PWEEK)
SHTIM = CT(SHEARW)
LDTIM = CT(LDWEEK)
HYTIM = CT(HYWEEK)
ST    =  CT(BSWEEK)



DYNAMIC
*
*=================================================  SECTION  6   ====
*

****TIMING VARIABLES AND SWITCHES****

NOSORT
YTIME = AMOD(TIME,52.)
NWYR = 1.-YTIME/(YTIME+NOT(YTIME))
RTIME = AMOD(TIME+SWEEK,52.)
MONTH = AFGEN(MONTT,RTIME)
*
*=================================================  SECTION  7   ====
*

* SOIL MOISTURE FACTOR
NYR=1.+YSEL+TIME/52.-AMOD(TIME,52.)/52.
*SM = TWOVAR(SMT,YTIME,NYR)
       SM = AFGEN(SMT,YTIME)
       ASM = 0.
       IF(SM.GT.0.001) ASM=1.
SORT


ASMWK = INTGRL(IAS,ASM - ASMWK*EGS/DELT)
PV=INTGRL(IPV,SM*750.-HARV1*PV/DELT)

*
*=================================================  SECTION  8   ====
*
**MACRO CALLS DONE,XTIM = CDX(ACT,MT)
```

```
* CALL MACRO MACT = 1 ON DAY OF ACT**
JOIN = MACT(JTIM)
LAM = MACT(LTIM)
CULL =MACT(CTIM)
SHEAR = MACT(SHTIM)
PLOW = MACT(PTIM)
HAY = MACT(HYTIM)
HARV1= MACT(HTIM)
BS  =  MACT(ST)
HARV=INSW(-HARV1,INSW(WG-MINGH,0.,1.),0.)
WG=(WG1+WG2+WG3+WG4)/(4.*(FRWHT+NOT(FRWHT))/(FRW+NOT(FRW)))


CTIM = WTIM+1.
WEAND,WTIM   = CDX(WEAN,PLOW)
SOLDW,SWTIM = CDX(SELLW,NWYR)
EGSD,ESTIM = CDX(EGS,GERM)
GERMD,GTIM = CDX(GERM,NWYR)

** GERMINATION AND END OF GROWING SEASON
PSM = DELAY(5,DELT,SM)
GERM = AND(0.01-PSM,SM-0.01)
EGS = AND(PSM-0.01,0.01-SM)

*
*======================================================  SECTION  9  ====
*

****ACCOUNTING ROUTINE****

* ANNUAL BALANCE
ANBAL=INTGRL(INBAL,GRINC-COST+(INSW(ANBAL,-LOANR/52.,DEPOSR/52.))*ANBAL)

*GROSS INCOME

GRINC =(PRLAM*NLAMSL*WLAM*SELLL+PRWNR*NWNRSL*WWNR*SELLW+PREWE*REPL ...
         *WEWE*CULL +WOOL*PRWOOL*SHEAR +GRAINH*PRGRN*SELLG+STSELL* ...
         PRSTR*PLOW +HSELL*PRHAY*PLOW )/DELT

*    WHEAT HARVEST AND WOOL CLIP****
GRAINH=FRW   *(WHARV1+WHARV2+WHARV3+WHARV4)/4.
WOOL = SHEAR*NEWES*WOOLSH

NWNRSL = AMAX1(0.,NWNRS-REPL)
PRLAM = AFGEN(PRLT,YTIME)*AFGEN(LWRT,WLAM)
PRWNR = AFGEN(PRLT,YTIME)*AFGEN(LWRT,WWNR)
PREWE = AFGEN(PRET,YTIME)*AFGEN(EWCONS,EWCON)
PRHAY = AFGEN(PRHT,YTIME)*HYYR
PRSTR = AFGEN(PRST,YTIME)*STYR
STYR =INTGRL(1.,UPDST/DELT)
HYYR =INTGRL(1.,UPDHY/DELT)

PROCEDURE UPDST,UPDHY = CALUP(HARV,STYR,HYYR)

       UPDST,UPDHY=SCALAR(ZUPD(1))
       IF(HARV1.EQ.0..OR.TIME.EQ.0.) GOTO 70
       UPDST = INSW(PP4    -3000.,SPINC,INSW(PP4    -6000.,-STYR+1.,    ...
               -SPINC))
       IF(STYR.LT.0.5.OR.STYR.GT.2.) UPDST = 0.
       UPDHY = INSW(PP4    -3000.,HPINC,INSW(PP4    -6000.,-HYYR+1.,    ...
               -HPINC))
       IF(HYYR.LT.0.5.OR.HYYR.GT.2.) UPDHY = 0.
   70 CONTINUE
ENDPROCEDURE




*PRIMARY PRODUCTION OF WHEAT = PP OF SECTION 4 OF WHEAT FIELD

PARAM HPINC =0.3, SPINC = 0.25
* HPINC,SPINC = FRACTIONAL PRICE INCREASE/DECREASE OF HAY,STRAW



*SELLING WEEK SWITCHES
SELLG = MACT(HTIM+1.)
SELLL = WEAN*(1.-RAISW)
```

```
PROCEDURE SELLW = CALSWN(SOLDW,WLWCH,SELLL,WWNR,NWNRS)
      SELLW = 0.
      IF(SOLDW.EQ.1..OR.RAISW.EQ.0.) GOTO 80
     IF((YTIME.EQ.PTIM-2.).OR.(WWNR.GT.SWW).OR.   ...
(NWNRS.GT.0..AND.WLWCH.LT.MINWGR) ...
        .OR.(SELLL.EQ.1.)) SELLW = 1.
   80 CONTINUE
ENDPROCEDURE



*COST CALCULATED AT END OF YEAR

PROCEDURE COST = CALCOS(NWYR,CONCF,COTW,GRAINH,BALST,BALHY)
      COST =0.
      IF(PLOW.NE.1.)GO TO 15
     CPAST = (FXPC+CFERT*AFERT+CPSEED*IGVP)*FRPAST
      CHARW =   FRWHT*FHC+AMAX1(0.,VHC*(GRAINH-250.))
      CSUPP = CONCF*PRCONC+COTW*PRCOTW
      CHARS = (RAKE*FRW+BALE*BALSC)* BALSC/(BALSC+NOT(BALSC))
      CHARH =(RAKE*FRW  +BALE*BALHC)*BALHC/(BALHC+NOT(BALHC))
      COST =(CPAST+CSUPP+INEWE*(CLPE+FXVPE*BREEDF+DEPOSR +   ...
        CHORM*INSW(1.-HORMT,1.,0.)) +                ...
                                         CCULTW*FRW+CHARW+CHARS+CHARH)/DELT
   15 CONTINUE
ENDPROCEDURE

*
*======================================================  SECTION  10  ===
*

****SHEEP POPULATION DYNAMICS****
NEWES = INTGRL(INEWE,(NWNRS*PLOW-REPL*CULL )/DELT-EMORT*NEWES/52.)

NLAMS = INTGRL(INL,(LAM*NEWES*(1.-CULLR)*LAMFR*LSURV-WEAN*NLAMS)/DELT)
LAMFR = BRDFR*ECON
BRDFR = INTGRL(IBRF,BREEDF*ECON*JOIN*HORM /DELT-BRDFR*WEAN/DELT)
ECON = AFGEN(EWCONB,EWCON)
HORM = INSW(EWCON-2.0,1.,HORMT)
LSURV = AFGEN(LAMRT,BRDFR)
NLAMSL = SELLL*AMAX1(0.,NLAMS-REPL1)
REPL1 = AMIN1(INEWE*CULLR,NLAMS)
REPL = INTGRL(IREP,(REPL1*WEAN-REPL*PLOW)/DELT)


PROCEDURE WEAN        = WEANPR(NLAMS,LTIM,WLAM,WEWE)
      WEAN = 0.
      IF(WEAND.EQ.1..OR.NLAMS.EQ.0.) GOTO 2
      IF((YTIME.GT.LTIM+THEW.AND.EARLW.EQ.1..AND.LMWCH.LT.0.2).OR.   ...
        (YTIME.GT.LTIM+4..AND.WEAND.EQ.0..AND.EWCON.LT.ECWN) .OR.   ...
        (YTIME.GE.ESTIM.AND.GPE+DPE.LT.300.).OR.                     ...
        (WLAM.GT.WLW).OR.(LMWCH.LT.0.1.AND.YTIME.GT.LTIM+4.).OR.    ...
(AGEW.GT.FWAGE).OR. ...
        (YTIME.EQ.JTIM-4..AND.WEAND.EQ.0.)) GOTO 1
      GOTO 2
    1 WEAN = 1.
      IF((WLAM.GT.50.).OR.(YTIME.GE.JTIM).OR.(LMWCH.LT.0.1.AND.      ...
        RAISW.EQ.0.)) SELLL = 1.
    2 CONTINUE
ENDPROCEDURE


*WEANERS ON PASTURE
NWNRS =INTGRL(INW,((REPL1+(NLAMS-REPL1)*RAISW )*WEAN-AMAX1(0.,NWNRS- ...
                 REPL )*SELLW -NWNRS*PLOW)/DELT)

*
*======================================================  SECTION  11  ===
*
**** ANIMAL BIOMASS ****

*EWE WEIGHT

WEWE=INTGRL(IWEW,EWCH*7.-((LAM*IWLAM*LAMFR*AFTBF)+PLOW*NWNRS ...
  *(WEWE-WWNR)/(NEWES+NWNRS))/DELT)
EWCON =(LIMIT(0.,5.,(WEWE-ZERO)*5./(MXBRW-ZERO))-LAM*0.2)

PROCEDURE EWCH = CALEWC(EWFB,LMWCH,WLAM)
      EWCH=EWFB*.55-LER*.62*(LMWCH/.77+KMNT*WLAM**.75)
      IF(EWCH.GE.0.) GOTO 90
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      EWCH = EWCH*15.481*0.62/(20.*0.8)
   90 CONTINUE
ENDPROCEDURE

EWEB = (EWINT*DIGPE-DIGDME+SUPPE)
EWINT = EGPI+EDPI
EGPI1= AMIN1(LIMIT(0.,PGCXE,GPE*EGEF*(1.+INSW(AGEW-4.,0.,1.)*LER     ...
      *WLAM/WEWE)),GPE/(7.*DELT))
EGPI = EGPI1*DEFERR
PGCXE = 2.+AMAX1(AMIN1(1.,LER*0.5),LER*MXDMIW)
PDCXE =1.5+AMAX1(AMIN1(.2,LER*0.1),LER*MXDMIW*DIGD/DIGG)
LER = NLAMS/NEWES
DIGDME =(KMNT*WEWE**0.75 ) ...
*INSW(-DEFERR,2.-AMAX1(EGPI1/PGCXE,EDPI1/PDCXE),1.)
PEDPI = LIMIT(0.,PDCXE,DPE*EGEF*(1.+INSW(AGEW-4.,0.,1.)*LER*WLAM/WEWE))
EDPI = EDPI1*DEFERR
EDPI1 = AMIN1(AMAX1(0.,PEDPI-EGPI),DPE/(7.*DELT))
DIGPE = (EGPI*DIGG+EDPI*DIGD)/(EWINT +NOT(EWINT))
DIGD= INSW(-EGSD,LIMIT(LDD,HDD,HDD-(HDD-LDD)*(YTIME-ESTIM)/HQDPP), ...
      INSW(-ASMWK,INSW(ASMWK-8.,0.4,HDD),LDD))
DEFERR=INSW(-AINCRE,1.,DEFER)

*NOTE - EWE INTAKE INCLUDES LAMB FORAGE INTAKE. DEFERR CANCELS DEFER=0.
*        WHEN EWES GRAZE WHEAT


* CALL PADOK MACRO FOR EWES
GPE,DPE,EGRZP,EIW1,EIW2,EIW3,EIW4,GRE1,GRE2,GRE3,GRE4   =   ...
PADOK(AINCRE,0.5)


*NOTE-GPE AND DPE CORRECTED FOR UNGRAZABLE RESIDUAL-SEE RZP,RZW IN MACRO

DEFER = INTGRL(IDEF,DEF)

* GRAZING DEFERMENT
PROCEDURE DEF,NDEF,GVSAT,GVSAFE,CRITGV,GVEQ = CALDF(GRVP,GVP,NEWES, ...
LDTIM,PGCXE,RZP)
      IF(YTIME.EQ.0.) NDEF = 0.
      DEF = 0.
      IF(YTIME.EQ.0.)GO TO 93
      IF(YTIME.LT.GTIM.OR.YTIME.GT.LDTIM) GOTO 99
      IF(YTIME.EQ.LDTIM) GOTO 97

* CALCULATE PASTURE CRITERIA FOR DEFERMENT
   93 GVSAT = PGCXE/EGEF+RZP
      GVSAFE = PGCXE*(NEWES/FRPAST)/(RGRPE+NOT(RGRPE))
      RGRPE = (GRVP/7.)/(GVP+NOT(GVP))
      HS = NEWES*EGEF
      GVEQ = HS*RZP/((HS-RGRPE)+NOT(HS-RGRPE))
      CRITGV = (GVSAFE+GVEQ)/2.

      IF((RGRPE.LT.EGEF*NEWES*SAFFE/FRPAST.AND.GVP.LE.GVSAT         ...
      .AND.DVP.LT.GVSAT).OR.(GVP.GT.                                 ...
          GVSAT.AND.PGCXE*NEWES*SAFF/FRPAST.GT.GRVP/7.).OR.      ...
      (EGPI1+EDPI1.      ...
       LT.TULP).OR.(YTIME.GE.GTIM.AND.YTIME.LT.GTIM+DEFW)) GOTO 94
      IF(DEFER.EQ.0.) GOTO 96
      GOTO 99
   94 IF(DEFER.EQ.1..AND.NDEF.LT.2.) GOTO 95
      IF(DEFER.EQ.1..AND.NDEF.EQ.2.) GOTO 99
      IF(DEFER.EQ.0..AND.YTIME.LT.LDTIM) GOTO 99
      GOTO 96
   95 IF( PGCXE*NEWES/FRPAST.GT.GRVP/7..AND.GVP.GT.AMIN1(CRITGV,    ...
                                      GVSAT))GO TO 99
      NDEF = NDEF+1.
      DEF = -1.
      GOTO 99
   96 DEF = 1.
      GOTO 99
   97 NDEF = 0.
      IF(DEFER.EQ.0.)DEF = 1.
   99 CONTINUE
ENDPROCEDURE


* EWE SUPPLEMENTATION-STRAW(SUPPES),HAY(SUPPEH),CONCENTRATE(SUPPEC)-
* USE COTTONWASTE WHEN NO STRAW.
```

```
PROCEDURE SUPPES,SUPPEH,SUPPEC,SUPECW=CSUPE(YTIME,LTIM,JTIM,DIGDME, ...
EGPI,EDPI,HSTAK,SSTAK,NEWES,DEFERR)

* AVAILABLE HAY,STRAW KGS DIG DM/EWE/DAY
      AVHAY = HSTAK/(NEWES*7.+NOT(NEWES))*DIGH
      AVSTR = SSTAK/(NEWES*7.+NOT(NEWES))*DIGS
      SUPPES,SUPPEH,SUPPEC,SUPECW=SCALAR(ZSUPP(1))
   IF((DEFERR.EQ.0.).OR.(EGPI+EDPI.LT.TULP))GO TO 6
      IF(EWCON.GT.ECSF) GO TO 12
      IF((YTIME.GT. LTIM -4..AND.YTIME.LE. LTIM+2.) .OR.          ...
        (YTIME.GT. JTIM -4..AND.YTIME.LE. JTIM +2.)) GO TO 9
      GOTO 10

*STEAM AND FLUSH
9 SUPPEH = DIGDME*(1.+FLUSH)-EGPI*DIGG-EDPI*DIGD
  IF(SUPPEH.LT.0.) SUPPEH = 0.
  IF(SUPPEH/DIGH.LE.1.5) GOTO 8
  SUPPEC = SUPPEH-1.5*DIGH
   SUPPEH = 1.5*DIGH
8 IF(SUPPEH.LT.AVHAY) GOTO 12
  SUPPEC = SUPPEH-AVHAY+SUPPEC
  SUPPEH = AVHAY
  GOTO 12

10 IF(D2SUPE.EQ.0..AND.EWCON.GT.CRASH)GO TO 12
    6 IF((YTIME.GT. LTIM -4..AND.YTIME.LE. LTIM+2.) .OR.          ...
        (YTIME.GT. JTIM -4..AND.YTIME.LE. JTIM +2.)) GO TO 9

*  SUPPLEMENT EWES TO MAITAIN BODYWEIGHT
  SUPPES = DIGDME-EGPI*DIGG-EDPI*DIGD+(LMWCH/0.77+KMNT*WLAM**.75)*LER
  IF(SUPPES.LT.0.) SUPPES = 0.
  IF(SUPPES/DIGS.LE.1.) GOTO 7
   SUPECW = SUPPES-1.*DIGS
   SUPPES = 1.*DIGS
  IF(SUPECW/DIGCW+SUPPES/DIGS.LE.1.25) GOTO 7
  SUPPEC = SUPECW-0.25*DIGCW
  SUPECW = 0.25*DIGCW
7 IF(SUPPES.LE.AVSTR) GOTO 12
   SUPECW = SUPPES-AVSTR+SUPECW
  SUPPES = AVSTR
12 CONTINUE
ENDPROCEDURE

* TOTAL EWE SUPPLEMENT (KGS DIG DM/EWE)
SUPPE = SUPPES+SUPPEH+SUPPEC+SUPECW



*LAMB WEIGHT

WLAM=INTGRL(IWL,IWLAM/DELT+LMWCH*7.*(1.-WEAN)-WEAN*WLAM/DELT)
IWLAM = AFGEN(BIRWT,LAMFR)*AFGEN(ECONLM,EWCON)*LAM
LMWCH = INSW(-D2SUPL,0.35,LMWC)*AFGEN(LGRT,LER   )    *NLAMS/       ...
            (NLAMS+NOT(NLAMS))
LMWC = INSW(EWCON-1.,LIMIT(0.,0.350,0.35*EWFB/(PGCXE*DIGG-DIGDME)),...
        AFGEN(LMWIT,AGEW)*(1.-EGSD*0.5))*NLAMS/(NLAMS+NOT(NLAMS))

*LAMB SUPPLEMENTATION

SUPPLC = INSW(YTIME-(LTIM  +4.),0.,INSW(YTIME-WTIM   ,SUPL,0.))
SUPL = D2SUPL*INSW(EGPI-PGCXE*0.9,2.*DIGDML*(1.-AMAX1(0.,(EGPI-   ...
                DIGDME/DIGG)/(PGCXE-DIGDME/DIGG))),0.)
DIGDML = KMNT*WLAM**0.75

*WEANER WEIGHT

WWNR = INTGRL(IWW,WLAM*  WEAN/DELT+WLWCH*7.*(1.-PLOW)-PLOW*WWNR/DELT)

WLWCH = WFBAL*0.62*AFGEN(ECWT,WWNR)
WFBAL = WGPI*DIGG+WDPI*DIGD+SUPPWC*DIGC-KMNT*WWNR**0.75
SUPPWC= D2SUPW*AMIN1(MXWSUP,WDPDF,AMAX1(0.,(KMNT*WWNR**0.75+    ...
        MINWGR/(0.62*AFGEN(ECWT,WWNR))-WGPI*DIGG-WDPI*DIGD)/DIGC))
WDPDF = AMAX1(0.,MXDMIW - WGPI - WDPI)*ZW
WDPI = AMIN1(DPW/(7.*DELT),AMAX1(0.,LIMIT(0.,MXDMIW,DPW*EGEF)-WGPI))*ZW
WGPI = AMIN1(GPW/(7.*DELT),LIMIT(0.,MXDMIW,GPW*EGEF))*ZW
MXDMIW = AFGEN(CXWT,AGEW)
AGEW = AMAX1(0.,YTIME-LTIM)
ZW=INSW(-NWNRS,1.,0.)
```

```
*CALL PADOK MACRO FOR WEANERS

GPW,DPW,WGRZP,WIW1,WIW2,WIW3,WIW4,GRW1,GRW2,GRW3,GRW4   =   ...
 PADOK(AINCRW,1.)

*   PADDOCK SWITCH FOR GRAZING EWES AND WEANERS IN WHEAT SECTIONS****
PROCEDURE INGWW,INGWE,ZAINC= CALIW(WEAN,AINCRW,FRWHT,WLWCH,GTIM,GVP  ...
,DVP,GPW,DPW,GPE,DPE,GVSAT,PGCXE,AINCRE)

* INCREMENT WHEAT SUBSECTION FOR WEANERS
      INGWW = 0.
      IF(WEAN.EQ.1.AND.RAISW.EQ.1..AND.(GVP+DVP-RZP)*FRPAST.LT.       ...
        10.5*INEWE*(52.+AWDP-YTIME)) INGWW=1.
      IF((AINCRW.GE.1.).AND.(AINCRW.LE.3.).AND.(WLWCH.LT.0.2).AND.    ...
         (GPW+DPW.LT.GVSAT/1.5)) INGWW = 1.

* INCREMENT WHEAT SUBSECTION FOR EWES
      INGWE = 0.
      MINW4G=10.*PGCXE*NEWES/(FRW/4.)
      IF(((YTIME.GE.GTIM+EWG).AND.(AINCRE.EQ.0.).AND.(DEFER.EQ.0.) ...
        .AND.(FRWHT.GT.0.01).AND.(D2GGW.EQ.1.).AND.                  ...
        (GVW+DVW.GT.AMAX1(MINW4G,GVSAT*SAFF)).AND.                   ...
        (D2SUPE.EQ.0.)).OR.                                          ...
        (AINCRE.EQ.0.AND.EGS.EQ.1.AND.WG4.LT.MINGH).OR.       ...
        (AINCRE.EQ.0..AND.YTIME.EQ.HYTIM+1..AND.                     ...
                                    GVW+DVW+WG4.LT.WFAIL))INGWE=1.


      IF((AINCRE.GE.1.).AND.(AINCRE.LE.3.).AND.(GPE+DPE.LT.GVSAT/2.))...
        INGWE=1.

*ZERO AINCRE
      ZAINC=0.
      IF(PLOW.EQ.1.OR.ASMWK.EQ.NOGEF.OR.GVW+DVW-RZW1.LE.0.)ZAINC=1.
ENDPROCEDURE


*MINW4G=MINIMUM WHEAT BIOMASS IN WHEAT SUBSECTION NECESSARY FOR 10 DAYS
*OF GRAZING

AINCRE = INTGRL(IAINE,(INGWE-(INGWE+AINCRE-4.)*HARV1-AINCRE*ZAINC)/DELT)
AINCRW = INTGRL(IAINW,(INGWW-(INGWW+AINCRW-4.)*HARV1-AINCRW*ZAINC)/DELT)


*FRACTION WHEAT,PASTURE AND GRAZED WHEAT (FRW = 1-FRPAST,SEE INITIAL SEC
FRWHT = (1.-FRPAST)-FRGWHT
FRGWHT = INTGRL(IFGW,(FRW/4.*INCFGW-FRGWHT*NWYR)/DELT)
INCFGW =        INSW(NOGEF-ASMWK,INSW(-FRWHT,INGWW+INGWE,0.),0.)

*
*===================================================  SECTION  12  ===
*

*  HAYSTAK,STRAWSTAK,CONCENTRATE FEED,COTTON WASTE**
SSTAK = INTGRL(ISST,BALST-SUPPES*NEWES*7./DIGS    -STSELL/DELT-    ...
        INSW(SSTAK-1.,1.,0.)*SSTAK/DELT)
BALST =   FRW  *(BLST1+BLST2+BLST3+BLST4)/(4.*DELT)
STSELL = INSW(MXSST-SSTAK,SSTAK-MXSST,0.)*PLOW
HSTAK = INTGRL(IHST,BALHY-SUPPEH*NEWES*7./DIGH-HSELL/DELT-   ...
                                    INSW(HSTAK-1.,1.,0.)*HSTAK/DELT)
BALHY = FRW  *(1.-HLOSS)*(BLHY1+BLHY2+BLHY3+BLHY4)/(4.*DELT)
HSELL = INSW(MXHST-HSTAK,HSTAK-MXHST,0.)*PLOW

*STRAW,HAY HARVESTED - FOR COST CALCULATION
BALSC = INTGRL(IBST,BALST-BALSC*NWYR/DELT)
BALHC = INTGRL(IBHY,BALHY-BALHC*NWYR/DELT)


*  CONCENTRATE FEED

CONCF = INTGRL(ICF,CONUSE-(CONCF/DELT+CONUSE)*NWYR)
CONUSE = (SUPPEC*NEWES+SUPPLC*NLAMS+SUPPWC*NWNRS)*7./DIGC

*  COTTON WASTE

COTW = INTGRL(ICW,SUPECW*NEWES*7./DIGCW-NWYR*COTW/DELT)

* DM CONSUMPTION BY SHEEP FROM PASTURE AND WHEAT

DMCPW = INTGRL(IDMC,(INGP+INDP)*FRPAST + (INGW1+INDW1+INGW2+INDW2+    ...
```

```
      INGW3+INDW3+INGW4+INDW4)*FRW/4. - DMCPW*NWYR/DELT)


*
*=====================================================  SECTION  13  ===
*

****GROWTH OF VEGETATION-PASTURE AND WHEAT****
*MACRO CALLS FOR  GROGV

*  AUX VARIABLES FOR MACRO GROGV
* WEGR=WEEKLY EXPONENTIAL GROWTH RATE (WHEN DELT=1.)
WEGR = EXP(RGR*SM*DELT*7.) - 1.
LOSS1 = INSW(-EGS,DMLOM/(7.*DELT),INSW(-ASMWK,AUX1,DML1))
AUX1 = INSW(ASMWK-8.,DML2,DML3)
SENESC = INSW(ASMWK-6.,0.,SENES)
TUDRY = INSW(SM-0.2,1.,0.)
BAYL = INSW(DVW*B-T,0.,INSW(E-DVW*FRW,1.,0.))*BS


GVP,DVP,GRVP,DRGVP,INGP,TRGP,LOSSP,INDP,SEED,SHARV,BLPS,BLPH,PPP,RZP...
     = GROGV(IGVP,FRGERM,EPTIM,EGRZP,WGRZP,FRPAST,EPTF,LPTF, ...
            TFVSP,0.,0.,0.,0.,0.,0.,ISP,IGP,IDVP,IPP,IRZP,0.,1.)

GVW1,DVW1,GRVW1,DRGVW1,INGW1,TRGW1,LOSSW1,INDW1,WG1,WHARV1,BLST1,   ...
BLHY1,PP1,RZW1                                                      ...
  = GROGV(IGVW,1.,EWTIM,EIW1,WIW1,FRW,EWTF,LWTF,TFVSW,GRE1,GRW1,...
        PLOW,HARV,HOP,SOP,IS1,IG1,ID1,IP1,IRZ1,IH1,0.)

GVW2,DVW2,GRVW2,DRGVW2,INGW2,TRGW2,LOSSW2,INDW2,WG2,WHARV2,BLST2,   ...
BLHY2,PP2,RZW2                                                   ...
=GROGV(IGVW,1.,EWTIM,EIW2,WIW2,FRW,EWTF,LWTF,TFVSW,GRE2,GRW2, ...
        PLOW,HARV,HOP,SOP,IS2,IG2,ID2,IP2,IRZ2,IH2,0.)

GVW3,DVW3,GRVW3,DRGVW3,INGW3,TRGW3,LOSSW3,INDW3,WG3,WHARV3,BLST3,   ...
BLHY3,PP3,RZW3                                                      ...
  =GROGV(IGVW,1.,EWTIM,EIW3,WIW3,FRW,EWTF,LWTF,TFVSW,GRE3,GRW3,...
        PLOW,HARV,HOP,SOP,IS3,IG3,ID3,IP3,IRZ3,IH3,0.)

GVW4,DVW4,GRVW4,DRGVW4,INGW4,TRGW4,LOSSW4,INDW4,WG4,WHARV4,BLST4,   ...
BLHY4,PP4,RZW4                                                      ...
  =GROGV(IGVW,1.,EWTIM,EIW4 ,WIW4,FRW,EWTF,LWTF,TFVSW,GRE4,GRW4,...
        PLOW,HARV,HOP,SOP,IS4,IG4,ID4,IP4,IRZ4,IH4,0.)

GVW=(GVW1+GVW2+GVW3+GVW4)/4.
DVW=(DVW1+DVW2+DVW3+DVW4)/4.


*
*=====================================================  SECTION  14  ===
*

*RUN CONTROL

OUTPUT NYR,MONTH,GVP,DVP,GRVP,DRGVP,INGP,TRGP,LOSSP,INDP,            ...
       SEED,SHARV,BLPS,BLPH,PPP,RZP,GVW,DVW,                      ...
       GVW1,DVW1,GRVW1,DRGVW1,INGW1,TRGW1,LOSSW1,INDW1,          ...
       WG1,WHARV1,BLST1,BLHY1,PP1,RZW1,                          ...
       GVW4,DVW4,GRVW4,DRGVW4,INGW4,TRGW4,LOSSW4,INDW4,          ...
       WG4,WHARV4,BLST4,BLHY4,PP4,RZW4,SM,ASMWK ,PV
LABEL  MIGDA SYSTEM-VEGETATION VARIABLES (KG/HA OF WHEAT OR PASTURE)

OUTPUT MONTH,GPE,DPE,GPW,DPW,NEWES,NLAMS,NWNRS,WEWE,EGPI,EDPI,EWFB,   ...
       DIGPE,                                                        ...
       WWNR,WGPI,WDPI,WFBAL,EIW1,WIW1,WIW4,AINCRE,AINCRW,DEFER,   ...
       BRDFR,NLAMS,WLAM,WOOL,SUPPES,SUPPEH,SUPECW,SUPPEC,       ...
       SUPPE,SUPPLC,SUPPWC,                                        ...
      ANBAL,GRINC,COST,NLAMSL,NWNRSL,GRAINH,STSELL,HSELL,  ...
       CONCF,COTW,DMCPW,SSTAK,HSTAK,BALHC,BALSC
LABEL  MIGDA SYSTEM-SHEEP,SUPPLEMENTARY FEED,ECONOMIC VARIABLES

TIMER FINTIM=52., DELT=1.,OUTDEL=1. ,PRDEL = 1.,TIME=0.
METHOD RECT
FINISH WEWE = ZERO
*
*=====================================================  SECTION  15  ===
*

*  PREPARE END OF YEAR REPORT
```

```
TABLE  SV(1-9)=8*0.
TABLE  MMV(1-24)=24*0.
PARAM A44=444., B55=555., C66=666., D77=777.,SPOUT=1.
PARAM POLICY=1., LBL=0., CHESHB=1.

PROCEDURE YM=CALMM(SELLL,SELLW,SELLG,WLAM,WWNR,GRAINH)

CALL  ARRAY(SELLL,SELLW,CULL,SHEAR,SELLG,PLOW,PLOW,PLOW,SV)
CALL  ARRAY(PRLAM,NLAMSL,WLAM,PRWNR,NWNRSL,WWNR,PREWE,REPL,WEWE,...
           PRWOOL,WOOL,A44,PRGRN,GRAINH,B55,PRSTR,STSELL,C66,  ...
           PRHAY,HSELL,D77,COST,CPAST,CSUPP,MMV)
      CALLOP=0.
      DO 71  J=1,8

      IF((SPOUT.EQ.1.).AND.(GERM.EQ.1..OR.EGS.EQ.1..OR.HAY.EQ.1..    ...
       OR.LAM.EQ.1..OR.WEAN.EQ.1..                                   ...
       OR.HARV1.EQ.1..OR.JOIN.EQ.1..OR.SV(J).EQ.1.))CALLOP=1.
      IF(SV(J).EQ.0.)GO TO 71
      DO 71 K=1,3
      K1=(J-1)*3+K
      YM(K1)=MMV(K1)
   71 CONTINUE
      IF (CALLOP.EQ.1.) CALL OUTPUT
ENDPROCEDURE


TERMINAL
      IF(LBL.GE.1.)GO TO 200
      WRITE(8,100)
      LBL=LBL+1.
  200 WRITE(8,101)POLICY,INEWE,ANBAL,PPP,PP4,DMCPW,CONCF,COTW,GRAINH
      IF(CHESHB.NE.1.)GO TO 201
      WRITE(8,102)
      WRITE(8,103)YM
      WRITE(8,104)
      LBL=0.
  201 CONTINUE

  100 FORMAT(3X,' POLICY  INEWE   ANBAL      PPP     PP4   DMCPW', ...
     '       CONF    COTW  GRAINH')
  101 FORMAT(1X,10F8.1)
  102 FORMAT(/1X,'ACCOUNT1-    PRLAM  NLAMSL     WLAM    PRWNR  NWNRSL',...
     '     WWNR    PREWE     REPL     WEWE  PRWOOL     WOOL')
  103  FORMAT(1X,'ACCOUNT1-',12F8.2/1X,'ACCOUNT2-',12F8.2)
  104 FORMAT(1X,'ACCOUNT2-    PRGRN  GRAINH',11X,'PRSTR  STSELL'11X,...
      'PRHAY   HSELL',12X,'COST   CPAST  CSUPPL')
TIMER FINTIM=52., OUTDEL=13., DELT=1.
END
STOP

      SUBROUTINE  PADOK (AINCR,EWOWN,
     $GPX,DPX,   ZP,  W1,  W2,  W3,  W4,G1   ,G2   ,G3   ,G4   )
COMMON

C GRAZE PASTURE OR NUMBER N WHEAT SUBSECTION WITH APPROPRIATE GPW,DPW
C WHEAT AREA DIVIDED INTO FOUR SUBSECTIONS,EACH FRW/4 HA.


C   OUTPUT N,GPW,DPW,GRW1,ETC., N=NUMBER OF WHEAT SUBSECTION SELECTED
      DO 19 I = 1,4
   19 WGRZW(I) = AMAX1(0.,AMIN1(1.,AINCR -(I-1)))
C     LOCKED  SWITCH
      G1 = WGRZW(1)
      G2 = WGRZW(2)
      G3 = WGRZW(3)
      G4 = WGRZW(4)
      CALL  ARRAY(GVW1,GVW2,GVW3,GVW4,GVWH)
      CALL  ARRAY(DVW1,DVW2,DVW3,DVW4,DVWH)
      CALL  ARRAY(RZW1,RZW2,RZW3,RZW4,RZW)
        ZP = 1.-WGRZW(1)
      IF(    ZP.EQ.1.) GOTO 32

C FIND WHEAT SUBSECTIONS WITH HIGHEST GREEN AND DRY BIOMASS
      GPX = AMAX1(GRW1*GVW1,GRW2*GVW2,GRW3*GVW3,GRW4*GVW4)
      DPX = AMAX1(GRW1*DVW1,GRW2*DVW2,GRW3*DVW3,GRW4*DVW4)
      IF(GPX+DPX.EQ.0.) GO TO 32
      IF(GPX.LT.500..AND.DPX.GT.2.*GPX) GOTO 23

C CHOOSE BY GREEN BIOMASS,SUBTRACT RESIDUAL FROM GREEN
```

```
      DO 22 I = 1,4
      IF(GPX-0.01.LT.GVWH(I)*WGRZW(I)) N = I
   22 CONTINUE
      DPX = DVWH(N)*WGRZW(N)
      GPX = GPX-RZW(N)*EWOWN
      GOTO 28

C CHOOSE BY DRY BIOMASS,SUBTRACT RESIDUAL FROM DRY
   23 DO 24 I = 1,4
      IF(DPX-0.01.LT.DVWH(I)*WGRZW(I)) N = I
   24 CONTINUE
      GPX = GVWH(N)*WGRZW(N)
      DPX = DPX-RZW(N)*EWOWN

C IF WHEAT BIOMASS LESS THAN GVSAT(WHEAT) AND LT PASTURE BIOMASS,SELECT
   28 IF(GPX+DPX.LT.1.5/EGEF.AND.GPX+DPX.LT.GVP+DVP-RZP*EWOWN)GO TO 32
      GO TO 29

C  ENTER PASTURE VALUES,SUBTRACT RESIDUAL FROM HIGHEST OF GREEN OR DRY
C BIOMASS (CHGD=CHOOSE GREEN OR DRY)
   32 CHGD=INSW(GVP-DVP,0.,1.)
      N=0
          ZP=1.
      GPX = GVP-RZP*EWOWN*CHGD-(1.-CHGD)*MNRZ
      DPX = DVP-RZP*EWOWN*(1.-CHGD)
   29 CONTINUE
      GPX = AMAX1(0.,GPX)
      DPX = AMAX1(0.,DPX)

C**EWOWN = 1.-WEANER CALL,     EWOWN = 0.5-EWE CALL

C    OUTPUT  WIW1 ETC.
      DO 30 I = 1,4
      WW(I) = 0.
      IF(I.EQ.N) WW(I) = 1.
  30  CONTINUE
      W1 = WW(1)
      W2 = WW(2)
      W3 = WW(3)
      W4 = WW(4)

      RETURN
      END
ENDJOB
```

Appendix II

DIRECTORY OF MIGDA SYSTEM MODEL VARIABLES

This directory includes all variables, parameters and names of function tables

DIRECTORY OF VARIABLES USED IN THE MIGDA SYSTEM
MODEL ARRANGED IN ALPHABETICAL ORDER
$$

COLUMN	MEANING
1	VARIABLE NAME
2	P = PARAMETER, F = FUNCTION TABLE I = INITIAL VALUE, BLANK = PROGRAM VARIABLE
3	DEFINITION OF VARIABLE
4	VARIABLE UNIT. '-' INDICATES DIMENSIONLESS
5	MODEL SECTION NUMBER IN WHICH VARIABLE APPEARS

		A A A		
AFERT	P	AMOUNT OF FERTILIZER	KG/HA	05
AFTBF	P	AFTER-BIRTH FACTOR FOR EWE-WT LOSS AFTER LAMBING		05
AGEW		AGE OF WEANER	WEEK	11
AINCRE		NO OF WHEAT SUBSECTIONS AVAILABLE FOR EWE GRAZING	SUBSECTIONS/HA	11
AINCRW		NO OF WHEAT SUBSECTIONS AVAILABLE FOR WEANER GRAZ	SUBSECTIONS/HA	11
ANBAL		ANNUAL BALANCE IN 'BANK'	IL/HA	09
ASM		CONDITIONS FOR GROWTH EXIST(1),DO NOT EXIST(0)	WEEK	07
ASMWK		WEEKS AFTER GERMINATION (=0 AFTER EGS)	WEEK	08
AUX1		AUX VARIABLE (WEATHERING RATES DURING GROWTH)	/DAY	13
AVWI	I	INITIAL AMT RESERVE SOIL-MOISTURE FOR TRANSPIRAT	MM	05
AWDP	P	ADDITIONAL DRY PASTURE RESERVE BEYOND NWYR	WEEK	05
		B B B		
B	P	FRACTION BALED OF POST-HARVEST DRY WHEAT BIOMASS	-	05
BALE	P	COST OF BALING	IL/KG	05
BALHC		TOTAL AMOUNT OF HAY BALED	KG/HA	12
BALHY		AMOUNT HAY BALED FROM ALL WHEAT SUBSECTIONS	KG/HA/YEAR	12
BALSC		TOTAL AMOUNT OF STRAW BALED	KG/HA	12
BALST		AMOUNT STRAW BALED FROM ALL WHEAT SUBSECTIONS	KG/HA/YEAR	12
BAYL		SWITCH - DECISION TO BALE STRAW(2) OR NOT(1)	-	13
BIRWT	F	BIRTH WT OF LAMBS (FN OF BRDFR)	-	04
BLHY1		AMOUNTH HAY BALED FROM EACH WHEAT SUB-SECTION	KG/HA/YEAR	13
BLPH		HAY BALED FROM PASTURE PADDOCK	KG/HA/WEEK	13
BLPS		STRAW BALED FROM PASTURE PADDOCK	KG/HA/WEEK	13
BLST1		AMOUNT STRAW BALED FROM EACH WHEAT SUBSECTION	KG/HA/YEAR	13
BRDFR		FERTILITY AFTER JOINING	-	10
BREEDF	P	POTENTIAL BREED FERTILITY (LAMBS/EWE)	-	05
BS		FLAG - TIME FOR BALING STRAW	-	08
BSWEEK		BALE STRAW DATE	WEEK (CALENDAR)	05
		C C C		
CAPINT	P	REDUNDANT	-	05
CCULTW	P	COST OF WHEAT CULTIVATION(PLOW,ETC,FERT,SEED,ETC)	IL/HA	05
CFERT	P	COST OF FERTILIZER	IL/KG	05
CHORM	P	COST OF HORMONE TREATMENT	IL/HEAD	05
CLPE	P	COST OF LABOUR PER EWE	IL/HEAD	05
CONCE		TOTAL AMOUNT OF CONCENTRATE UTILIZED	KG/HA	12
CONUSE		TOTAL RATE OF CONCENTRATE CONSUMPTION	KG/HA/WEEK	12
COST		TOTAL OPERATIONAL EXPENSES	IL/HA/YEAR	09
COTW		TOTAL AMOUNT OF COTTON-GIN WASTE UTILIZED	KG/HA	12
CPSEED	P	COST OF PASTURE SEED	IL/KG	05
CRASH	P	EWE CONDITION FOR SUPPLEMENTARY FEEDING	-	05
CRITGV		THRESHOLD FOR NEGATIVE NET GROWTH UNDER GRAZING	KG/HA	11
CTIM		CULLING DATE	WEEK(YTIME)	08
CULL		FLAG - TIME TO CULL	-	08
CULLR	P	CULLING RATE	-	05
CULLS		ADULT SHEEP SOLD AFTER WEANING	NUMBER	05
CXWT	F	MAX DM CONSUMP OF WEANERS WITH AGE (FN OF AGEW)	KG/HEAD/DAY	04
		D D D		
D2GGW	P	SWITCH - MGT DECISION TO GRAZE GREEN WHEAT	-	05
D2SUPE	P	SWITCH - MGT DECISION TO SUPL FEED EWES(1,0)	-	05
D2SUPL	P	SWITCH - MGT DECISION TO SUPL FEED LAMBS (1,0)	-	05
D2SUPW	P	SWITCH - MGT DECISION TO SUPL FEED WEANERS (1,0)	-	05
D7		DELT*7=CONVERTS DAILY RATES TO WEEKLY RATES	DAYS	05
DEF		SWITCH ACTIVATOR (SEE DEFER)	-	11
DEFER		SWITCH - GRAZING DEFERRED(0) OR NOT (1)	-	11

DEFERR		SWITCH - EWES ON PASTURE(1) OR NOT (0)	-	11
DEFTHR	P	GREEN PHYTOMASS THRESHOLD FOR DEFERMENT-REDUNDANT	KG/HA	05
DEFW	P	ARBITRARY GRAZING DEFER PERIOD AFTER GERMINATION	WEEK	05
DEPOSR	P	DEPOSIT INTEREST	/YEAR	05
DIGC	P	DIGESTIBILITY OF CONCENTRATE FEED	-	05
DIGCW	P	DIGESTIBILITY OF COTTON-GIN WASTE	-	05
DIGD		DIGESTIBILITY OF DRY PASTURE (FRACTION)	-	11
DIGDME		DIGESTIB DM REQUIREMENT OF EWE FOR MAINTENANCE	KG/HEAD/DAY	11
DIGDML		DIGESTIB DM REQUIREMENT FOR LAMB MAINTENANCE	KG/HEAD/DAY	11
DIGG	P	DIGESTIBILITY OF GREEN PASTURE	-	05
DIGH	P	DIGESTIBILITY OF HAY	-	05
DIGPE		DIGESTIB GREEN PASTURE CONSUMED BY EWES	-	11
DIGS	P	DIGESTIBILITY OF STRAW	-	05
DMCPW		TOTAL DRY MATTER CONSUMPTION (WHEAT +PASTURE)	KG/HA	12
DML1	P	DRY VEGET LOSS RATE IN SUMMER	/DAY	05
DML2	P	DRY VEGET LOSS RATE AT BEGIN OF GROWING SEASON	/DAY	05
DML3	P	DRY VEGET LOSS RATE AT END OF GROWING SEASON	/DAY	05
DMLOM	P	DRY MATTER LOSS ON MATURITY OF VEGETATION	-	05
DPE		DRY PHYTOMASS AVAILABLE TO EWES	KG/HA	11
DPW		DRY PHYTOMASS AVAILABLE TO WEANERS	KG/HEAD/DAY	11
DRGVP		DRYING RATE OF GREEN PHYTOMASS(PASTURE)	KG/HA/WEEK	13
DRGVW1		DRYING RATE OF GREEN PHYTOMASS (WHEAT)	KG/HA/WEEK	13
DRYR	P	DRYING RATE OF VEGETATION AFTER END OF GR.SEASON	/DAY	05
DVF		DRY PHYTOMASS - PASTURE DM	KG/HA	13
DVW		DEAD WHEAT PHYTOMASS	KG/HA	13
DVW1		DRY PHYTOMASS - WHEAT SUBSECTIONS(1-4) DM	KG/HA	13

E E E

E		=EWSREQ=EWE REQ FOR WHEAT STUBBLE IN SUMMER	KG/SEASON	05
EARLW	P	SWITCH - EARLY WEANING SYSTEM(1) OR NOT(0)	-	05
ECON		EFFECT OF EWE CONDITION ON FERTILITY	-	10
ECONLM	F	REDUC FAC ON LAMB BIRTH WT (FN OF EWCON)	-	04
ECSF	P	EWE CONDITION THRESHOLD FOR STEAM AND FLUSH	-	05
ECWN	P	EWE CONDITION THRESHOLD FOR WEANING	-	05
ECWT	F	DIGEST DM CONVERSION EFFIC TO LW (FN OF WWNR)	-	04
EDPI		EWE-LAMB DRY PASTURE INTAKE (ACTUAL)	KG/HEAD/DAY	11
EDPI1		EWE-LAMB DRY PASTURE INTAKE CORRECTED FOR EGPI	KG/HEAD/DAY	11
EGEF	P	EWE GRAZING EFFICIENCY (=S IN NOY-MEIR PUBLICAT)	HA/DAY	05
EGPI		EWE GREEN PASTURE INTAKE (ACTUAL)	KG/HEAD/DAY	11
EGPI1		EWE GREEN PASTURE INTAKE (POSSIBLE)	KG/HEAD/DAY	11
EGRZP		SWITCH - EWES GRAZING IN PASTURE PADDOCK(1,0)	-	11
EGS		FLAG - END OF GROWING SEASON	-	08
EGSD		SWITCH - PAST EGS(1) OR NOT (0)	-	08
EGWEEK	P	LAST POSSIBLE GERMINATION DATE	WEEK(CALENDAR)	05
EIW1		SWITCH - EWES IN WHEAT SUBSECTION(1-4) OR NOT(1,0)		11
EMORT	P	EWE MORTALITY RATE/YEAR	/YEAR	05
EPTF	P	EARLY PASTURE SEEDFILL (FRACT OF NET GROWTH)	-	05
EPTIM		LAST POSSIBLE DATE FOR PASTURE GROWTH	WEEK (YTIME)	05
EPWEEK	P	DATE AFTER WHICH PASTURE ALWAYS DRY	WEEK(CALENDAR)	05
ESTIM		EGS DATE	WEEK (YTIME)	08
EVBS	P	EVAPORATION CONSTANT FOR DRY SOIL	/DAY	05
EWCH		EWE LIVE-WEIGHT CHANGE	KG/HEAD/DAY	11
EWCON		EWE CONDITION	-	11
EWCONB	F	EWE FERTILITY FACTOR AT JOINING (FN OF EWCON)	-	04
EWCONS	F	PRICE REDUC FAC DUE TO EWE CONDIT (FN OF EWCON)	-	04
EWFB		EWE FEED BALANCE (DIGESTIB DM)	KG/HEAD/DAY	11
EWG	P	EARLIEST WHEAT GRAZING WEEK AFTER GERMINATION	WEEK	05
EWINT		EWE-LAMB GREEN + DRY PASTURE INTAKE	KG/HEAD/DAY	11
EWTF	P	EARLY WHEAT SEEDFILL (FRACT OF NET GROWTH)	-	05
EWTIM		LAST POSSIBLE DATE FOR WHEAT GROWTH	WEEK (YTIME)	05
EWWEEK	P	DATE AFTER WHICH WHEAT ALWAYS DRY	WEEK(CALENDAR)	05

F F F

FHC	P	FIXED HARVEST COST	IL/HA	05
FLUSH	P	FEED REQUT ABOVE EWE MAINT DURING BREEDNG,LAMBNG	-	05
FRGERM	P	FRACTION OF PASTURE SEEDS WHICH GERMINATE	-	05
FRGWHT		FRACTION OF FARM UNDER WHEAT GRAZING	-	11
FRHARW	P	FRACTION WHEAT GRAIN HARVESTED	-	05
FRPAST	P	FRACTION OF AREA UNDER PASTURE	-	05
FRW		FRACTION OF FARM UNDER WHEAT	-	05
FRWHT		FRACTION WHEAT NOT GRAZED	-	11
FWAGE	P	FORCED WEANING AGE	WEEKS	05
FXPC	P	FIXED PASTURE COSTS (FENCING,WATER,RENT,ETC)	IL/HA	05
FXVPE	P	FIXED VET COSTS PER EWE	IL/HEAD	05

G G G

GERM		FLAG - TIME TO GERMINATE	-	08

GERMD		SWITCH-PASTURE AND WHEAT GERMINATED(1) OR NOT (0)	-	08
GGWH	P	GRAZE GREEN WHEAT (=D2GGW,REDUNDANT)	-	05
GPE		GREEN PHYTOMASS AVAILABLE TO EWES	KG/HA	11
GPTH	P	GREEN PASTURE THRESHOLD (REDUNDANT)	KG/HA	05
GPW		GREEN PHYTOMASS AVAILABLE TO WEANERS	KG/HA	11
GRAINH		WHEAT HARVESTED	KG/HA/YEAR	09
GRE1		SWITCH - WHEAT SUBSECTION(1-4) GRAZED BY EWES	-	11
GRINC		GROSS INCOME	IL/HA/YEAR	09
GRVP		GROWTH RATE OF VEGETATIVE PHYTOMASS(PASTURE)	KG/HA/WEEK	13
GRVW1		GROWTH RATE OF VEGETATIVE BIOMASS (WHEAT)	KG/HA/WEEK	13
GRW1		SWITCH - WHEAT SUBSECTION(1-4) GRAZED BY WEANERS	-	11
GTIM		GERMINATION DATE	WEEK(YTIME)	08
GVEQ		EQUILIBRIUM POINT - PASTURE GROWTH=CONSUMPTION	KG/HA	11
GVP		GREEN PHYTOMASS - PASTURE DM	KG/HA	13
GVSAFE		AMOUNT PHYTOM NEEDED FOR NET GROWTH UNDER GRAZING	KG/HA	11
GVSAT		GREEN PHYTOMASS NECESSARY FOR SATIATION INTAKE	KG/HA	11
GVW		MEAN GREEN VEGETATIVE PHYTOMASS IN WHEAT SUBSECTS	KG/HA	13
GVW1		GREEN PHYTOMASS - WHEAT SUBSECTIONS(1-4) DM	KG/HA	13
		H H H		
HARV		DECIDE TO HARVEST(1) OR NOT(0) DEPENDANT ON WG	-	08
HARV1		FLAG - TIME TO HARVEST WHEAT	-	08
HAY		FLAG - TIME FOR HAY-MAKING	-	08
HDD	P	HIGH VALUE FOR DRY PASTURE DIGESTIBILITY	-	05
HLOSS	P	DM LOSS IN HAYMAKING	-	05
HOP	P	=D2BP IN MACRO GROGV=CUT WHEAT HAY OPTION(0,1)	-	05
HORM		FERTILITY FACTOR DUE TO HORMONE TREATMENT	-	10
HORMT	P	FERTILITY FACTOR DUE TO HORMONE TREATMENT	-	05
HPINC	P	PRICE INCREASE/DECREASE OF HAY SEASON-DEPENDNT	-	05
HQDPP	P	HIGH QUALITY DRY PASTURE PERIOD	WEEKS	05
HSELL		AMOUNT HAY SOLD	KG/HA/YEAR	12
HSTAK		HAY STACK	KG/HA	12
HTIM		HARVEST DATE	WEEK (YTIME)	05
HWEEK	P	HARVEST DATE	WEEK(CALENDAR)	05
HYTIM		DATE TO DECIDE WHETHER TO CUT WHEAT FOR HAY	WEEK (YTIME)	05
HYWEEK	P	DATE TO DECIDE WHETHER TO CUT WHEAT FOR HAY	WEEK(CALENDAR)	05
HYYR		HAY PRICE FACTOR	-	08
		I I I		
IAIME	I	INIT. ACCUMULATED INCREMENT OF WHEAT-EWES 000	-	11
IAINW	I	INIT. ACCUMULATED INCREMENT OF WHEAT-WEANERS 000	-	11
IAS	I	INIT. WEEKS AFTER GERMINATION 000	WEEK	07
IBHY	I	INIT. BALED HAY 000	KG/HA	12
IBRF	I	INIT. BREEDING FACTOR	-	10
IBST	I	INIT. BALED STRAW 000	KG/HA	12
ICF	I	INIT. CONCENTRATED FEED 000	KG/HA	12
ICW	I	INIT. COTTON GIN WASTE 000	KG/HA	12
ID1	I	INIT. DRY PHYTOMASS-WHEAT SUBSECTIONS(1-4) 000	KG/HA	01
IDEF	I	INIT. DEFERMENT OF GRAZ ON PASTURE(0=DEFER,1=NO)	-	11
IDMC	I	INIT. DM CONSUMED FROM WHEAT AND PASTURE 000	KG/HA	12
IDVP	I	INITIAL DRY PASTURE	KG/HA	05
IFGW	I	INIT. FRACTION OF GRAZED WHEAT AREA 000	-	11
IG1	I	INIT. GREEN PHYTOMASS-WHEAT DM SUBSECTS(1-4) 000	KG/HA	01
IGP	I	INITIAL GREEN VEG IN PASTURE (MIDSEASON RUNS)	KG/HA	05
IGVP	P	PASTURE SEED SOWN	KG/HA	05
IGVW	P	WHEAT SEED SOWN	KG/HA	05
IH1	I	INIT. GRAIN YIELD HARVESTED SUBSECTIONS(1-4) 000	KG/HA	01
IHST	I	INIT. HAY STACK 000	KG/HA	12
IMGR	I	INIT MEASURED BIOMASS VALUE(FOR DERIV FUNCTION)	KG/HA	05
INBAL	I	INITIAL BANK BALANCE	IL/HA	
INCFGW		RATE OF OPENING WHEAT SUBSECTIONS TO GRAZING	SUBSECTIONS/WEEK	11
INDP		DRY PASTURE CONSUMPTION RATE BY HERD	KG/HA/WEEK	13
INDW1		DRY WHEAT CONSUMPTION RATE BY HERD IN SUBSECT	KG/HA/WEEK	13
INEWE	I	INITIAL NO. OF EWES/HA	HEAD/HA	05
INGP		GREEN PASTURE CONSUMPTION RATE BY HERD	KG/HA/WEEK	13
INGW1		GREEN WHEAT CONSUMPTION RATE BY HERD IN SUBSECT	KG/HA/WEEK	13
INGWE		INCREMENT WHEAT SUBSECTION FOR EWES	SUBSECTION/WEEK	11
INGWW		INCREMENT WHEAT SUBSECTION FOR WEANERS	SUBSECTION WEEK	11
INLAM	I	INITIAL NO. OF LAMBS/HA 000	HEAD/HA	05
INL	I	INIT. NO OF LAMBS 000	HEAD/HA	10
INW	I	INIT. NO OF WEANERS 000	HEAD/HA	10
IP1	I	INIT. PRIMARY PRODUCTION -WHEAT SUBSECTS(1-4) 000	KG/HA	01
IPV	I	INIT. POTENTIAL PRODUCTION - PASTURE 000	KG/HA	07
IREP	I	INIT. NO OF REPLACEMENTS 00	HEAD/HA	10
IRZ1	I	INIT. RESIDUAL UNGRAZABLE PHYTOMASS WHEAT (1-4)	KG/HA	01
IS1	I	INIT. STANDING SEED IN WHEAT SUBSECTS(1-4) 000	KG/HA	01
ISP	I	INIT. SEED STOCK OR STANDING SEED IN PASTURE	KG/HA	01
ISST	I	INIT. STRAW STACK 000	KG/HA	12

IWEW	I	INITIAL WEIGHT OF EWE	KG/HEAD	05
IWL	I	INIT. WEIGHT OF LAMBS 000	KG/HEAD	11
IWLAM		BIRTH-WEIGHT OF LAMB	KG/HEAD/DAY	11
IWW	I	INIT. WEIGHT OF WEANERS 000	KG/HEAD	11

J J J

JOIN		FLAG - TIME TO BREED	-	08
JTIM		JOINING DATE	WEEK (YTIME)	05
JWEEK	P	JOINING DATE	WEEK(CALENDAR)	05

K K K

KMNT	P	MAINTENANCE COEFFICIENT (KG DM)/(KG METABOL WT)	-	05

L L L

LAM		FLAG - TIME TO LAMB	-	08
LAMFR		LAMBING RATE	-	10
LAMRT	F	LAMB MORTALITY RATE (FN OF BRDFR)	-	04
LBL		SWITCH TO PRINT HEADINGS	-	15
LDD	P	LOW VALUE FOR DRY PASTURE DIGESTIBLITY	-	05
LDTIM		LAST POSSIBLE DATE FOR GRAZING DEFERMENT	WEEK (YTIME)	05
LDWEEK	P	DATE AFTER WHICH GRAZING CANNOT BE DEFERED	WEEK(CALENDAR)	05
LER		LAMB/EWE RATIO	-	11
LGRT	F	LAMB GROWTH RATE REDUCT FACT (FN OF LER)	-	04
LGTIM		LAST POSSIBLE GERMINATION DATE	WEEK (YTIME)	05
LMWC		LAMB LIVE-WEIGHT CHANGE(NO SUPPLEMENTS)	KG/HEAD/DAY	11
LMWCH		LAMB LIVE-WEIGHT CHANGE (WITH SUPPLEMENTS)	KG/HEAD/DAY	11
LMWIT	F	POTENTIAL LAMB WT GAIN (FN OF AGEW)	KG/HEAD/DAY	04
LOANR	P	LOAN INTEREST	/YEAR	05
LOSS1		RELATIVE WEATHERING RATE	/DAY	13
LOSSP		WEATHERING,TRAMPLING LOSS OF DRY PHYTOM (PASTURE)	KG/HA/WEEK	13
LOSSW1		WEATHERING,TRAMPLING LOSS OF DRY PHYTOMASS(WHEAT)	KG/HA/DAY	13
LPTF	P	LATE PASTURE SEEDFILL (FRACT OF NET GROWTH)	-	05
LSURV		LAMB SURVIVAL RATE	-	10
LTIM		LAMBING DATE	WEEK (YTIME)	05
LWEEK		LAMBING DATE - 21 WEEKS AFTER JOINING	WEEK (CALENDAR)	05
LWRT	F	REDUC FAC DUE TO LOW LWT (FN OF WWNR,WLAM)	-	04
LWTF	P	LATE WHEAT SEEDFILL (FRACT OF NET GROWTH)	-	05

M M M

M	P	TRANSPIRATION/DM RATIO (KG TRANSP WATER/KG DM)	-	05
MGCT	F	MEASURED GROWTH CURVE (FN OF YTIME)	KG/HA	04
MINGH	P	MIN. AMOUNT OF GRAIN FOR HARVEST DECISION	KG/HA	05
MINRW	P	MINIMUM LAMB WEIGHT FOR REPLACEMENT	KG/HEAD	05
MINSS	P	MINIMUM SEED STOCK IN SOIL (NEVER ZERO)	KG/HA	05
MINWGR	P	MINIMUM WEANER DAILY GROWTH RATE	KG/HEAD/DAY	05
MNRZ	P	MINIMUM UNGRAZABLE RESIDUAL VEGETATION	KG/HA	05
MONTH		CALENDAR MONTH	-	06
MONTT	F	TABLE TO CONVERT MODEL TIME TO CALENDAR MONTHS	MONTH	04
MXBRW	P	MAX WEIGHT OF BREED	KG/HEAD	05
MXDMIN		MAX DM INTAKE OF WEANERS	KG/HEAD/DAY	11
MXGR	P	MAXIMUM GROWTH RATE OF VEGETATION	KG/HA/DAY	05
MXHST		MAX HAY STORAGE ALLOWED	KG/SEASON	05
MXSST		MAX STRAW STORAGE ALLOWED	KG/SEASON	05
MXWSUP	P	MAXIMUM WEANER SUPPLEMENTARY FEED(KG DIG.CONC)	KG/HEAD/DAY	05

N N N

NDEF		NO TIMES GRAZING IN PASTURE PADDOCK WAS DEFERRED	-	11
NEWES		NO EWES IN FLOCK	HEAD/HA	10
NLAMS		NO LAMBS IN FLOCK	HEAD/HA	10
NLAMSL		NO LAMBS SOLD	HEAD/YEAR	10
NOGEF	P	EARLY WHEAT GROWTH PERIOD - NO GRAZ DAMAGE 2 WHT	WEEK	05
NWNRS		NO OF WEANERS IN FLOCK	HEAD/HA	10
NWNRSL		NO WEANERS SOLD	HEAD/YEAR	09
NWYR		FLAG BEGINNING OF BUDGET YEAR (YTIME=0)	-	
NYR		NO OF YEAR IN SERIES OF YEARS	-	07

P P P

PDCXE		MAX DRY PASTURE INTAKE BY EWE-LAMB UNIT	KG/HEAD/DAY	11
PEDPI		POTENTIAL EWE-LAMB UNIT PASTURE INTAKE	KG/HEAD/DAY	11
PGCXE		MAX GREEN PASTURE INTAKE BY EWE-LAMB UNIT	KG/HEAD/DAY	11
PLOW		FLAG - TIME TO PLOW	-	08
PP1		PRIMARY PRODUCTION - WHEAT SUBSECTIONS(1-4) DM	KG/HA	13
PPP		PRIMARY PRODUCTION - PASTURE DM	KG/HA	13
PRCONC	P	PRICE OF CONCENTRATE FEED	IL/KG	05

PRCOTW	P	PRICE OF COTTON WASTE	IL/KG	05
PRET	F	PRICE OF EWE LIVEWEIGHT (FN OF YTIME)	IL/KG	04
PREWE		PRICE OF EWE	IL/KG	09
PRGR	P	POTENTIAL RELATIVE GROWTH RATE	/DAY	05
PRGRN	P	PRICE OF GRAIN	IL/KG	05
PRHAY		PRICE OF HAY	IL/KG	09
PRHT	F	PRICE OF HAY (FN OF YTIME)	IL/KG	04
PRLAM		PRICE OF LAMB	IL/KG	09
PRLT	F	PRICE OF LAMB LIVEWEIGHT (FN OF YTIME)	IL/KG	04
PRST	F	PRICE OF STRAW (FN OF YTIME)	IL/KG	04
PRSTR		PRICE OF STRAW	IL/KG	09
PRWNR		PRICE OF WEANER	IL/KG	09
PRWOOL	P	PRICE OF WOOL	IL/KG	05
PSM		VALUE OF SM IN PREVIOUS WEEK	-	08
PTIM		PLOW DATE	WEEK (YTIME)	05
PV		REDUNDANT	-	07
PWEEK	P	PLOWING DATE	WEEK(CALENDAR)	05

R R R

R		=FRR=FRACT OF WHEAT STRAW REMAINING AFTER BALING	-	05
RAISW	P	SWITCH- RAISE WEANERS(1) OR SELL LAMBS(0)		05
RAKE	P	COST OF RAKING	IL/HA	05
REPL		NO OF REPLACEMENT WEANERS IN FLOCK	HEAD/HA	10
REPL1		NO WEANERS TO BE LEFT AS REPLACEMENT FOR CULLS	HEAD/YEAR	10
RTIME		CALENDAR WEEK (REAL TIME)	-	06
RZP		UNGRAZABLE RESIDUAL VEGETATION IN PASTURE	KG/HA	13
RZW1		UNGRAZABLE RESIDUAL VEGETATION IN WHEAT SUBSECTS	KG/HA	13

S S S

SAFF	P	SAFETY FACTOR FOR DEFERMENT (GVP GT GVSAT)	-	05
SAFFE	P	SAFETY FACTOR FOR DEFERMENT (GVP LE GVSAT)	-	05
SEED		PASTURE SEED PRODUCED	KG/HA	13
SELLG		FLAG - TIME TO SELL GRAIN	-	09
SELLL		FLAG - TIME TO SELL LAMBS	-	09
SELLW		FLAG - TIME TO SELL WEANERS	-	09
SENES	P	DRYING RATE OF GREEN PHYTOMASS	/DAY	05
SENESC		RELATIVE SENESCENCE RATE OF PHYTOMASS	/DAY	13
SHARV		SEED REMOVED BY HARVEST OF PASTURE (FOR HAY)	KG/HA	13
SHEAR		FLAG - TIME TO SHEAR	-	08
SHEARW	P	SHEARING DATE	WEEK(CALENDAR)	05
SHTIM		SHEEP SHEARING DATE	WEEK (YTIME)	05
SLWK	P	PASTURE SEED LOSS RATE/WEEK DUE TO INSECTS,BIRDS	/WEEK	05
SM		GROWTH CONTROL FACTOR (SOIL MOISTURE MAINLY)	-	07
SMT	F	GROWTH RED FAC DUE TO SOIL MOIST ETC (FN OF YTIME)	-	04
SOLDW		SWITCH - WEANERS SOLD(1) OR NOT(0)	-	09
SOP	P	=D2BS IN MACRO GROGV= BALE STRAW OPTION (0,1)	-	05
SPINC	P	PRICE INCREASE/DECREASE OF STRAW	-	05
SSTAK		STRAW STACK	KG/HA	12
ST		BALE STRAW DATE	WEEK (YTIME)	05
STSELL		AMOUNT STRAW SOLD	KG/HA/YEAR	12
STWST	P	STRAW WASTAGE DUE TO GRAZING -REDUNDANT(=WASTE)	-	05
STYR		STRAW PRICE FACTOR	-	08
SUPL		DIGESTIB DM SUPPLEMENT FOR LAMB (AUXILLIARY)	KG/HEAD/DAY	11
SUPPE		DIGESTIB DM SUPPLEMENT TO EWES - TOTAL	KG/HEAD/DAY	11
SUPPEC		DIGESTIB DM SUPPLEMENT TO EWES - CONCENTRATE	KG/HEAD/DAY	11
SUPPEH		DIGESTIB DM SUPPLEMENT TO EWES-HAY	KG/HEAD/DAY	11
SUPPES		DIGESTIB DM SUPPLEMENT TO EWES-STRAW	KG/HEAD/DAY	11
SUPPEW		DIGESTIB DM SUPPLEMENT TO EWES - COTTON-GIN WASTE	KG/HEAD/DAY	11
SUPPLC		DIGESTIB DM SUPPLEMENT FOR LAMB (CONCENTRATE)	KG/HEAD/DAY	11
SUPPWC		SUPPLEMENTARY FEED (CONCENTRATE) FOR WEANERS	KG/HEAD/DAY	11
SWEEK		CALENDER WEEK WHEN YTIME=0	WEEK(CALENDAR)	05
SWTIM		DATE WEANERS SOLD	WEEK(YTIME)	08
SWW	P	SALE WEIGHT OF WEANERS	KG/HEAD	05

T T T

T	P	THRESHOLD STUBBLE WEIGHT FOR BALING	KG/HA	05
TFVSP	P	TRANSLOC FRAC VEGET TO SEED AT MATURITY -PASTURE	-	05
TFVSW	P	TRANSLOC FRAC VEGET TO SEED AT MATURITY -WHEAT	-	05
THGSR	P	THRESHOLD GRAIN STRAW RATIO FOR WHEAT HAY DECISN		05
TRGP		FRACTION OF GROWTH INCREMENT TO SEED-FILL(PASTURE)	-	13
TRGW1		FRACTION OF GROWTH INCREMENT TO SEED FILL(WHEAT)	-	13
TUDRY		SWITCH - CUT FOR HAY(1) OF NOT(0),SM-DEPENDENT	-	13
TULP	P	EWE PASTURE INTAKE THRESHOLD FOR GRAZING DEFERMT	KG/HEAD/HAY	05

U U U

UPDHY		FACTOR TO UPDATE PRICE OF HAY	-	08

UPDST		FACTOR TO UPDATE PRICE OF STRAW	-	08
		V V V		
VHC	P	VARIABLE HARVEST COST KG	IL/KG	05
		W W W		
W2BS	P	DELAY BETWEEN GRAIN HARVEST AND STRAW BALING	WEEKS	05
WASTE	P	WASTAGE FACTOR-DRY MATTER LOSS DUE TO TRAMPLING	-	05
WDPDF		WEANER DRY PASTURE DEFICIT	KG/HEAD/DAY	11
WDPI		WEANER DRY PASTURE INTAKE	KG/HEAD/DAY	11
WEAN		FLAG - TIME TO WEAN	-	10
WEAND		SWITCH - LAMBS WEANED(1) OR NOT (0)	-	08
WEGR		WEEKLY RELATIVE GROWTH RATE DURING EXPONENTIAL GR	/WEEK	13
WEWE		EWE LIVE-WEIGHT	KG/HEAD/DAY	11
WFAIL	P	WHEAT FAILURE THRESHOLD TO ALLOW EWES TO GRAZE	KG/HA	05
WFBAL		WEANER FEED BALANCE	KG/HEAD/DAY	11
WG		WHEAT GRAIN YIELD ON SECTIONS THAT WERE NOT GRAZED	KG/HA	08
WG1		WHEAT GRAIN PRODUCED IN SUBSECTIONS(1-4)	KG/HA	13
WGPI		WEANER GREEN PASTURE INTAKE	KG/HEAD/DAY	11
WGRZP		SWITCH - WEANERS IN PASTURE PADDOCK(1,0)	-	11
WHARV1		WHEAT GRAIN HARVESTED IN WHEAT SUBSECTIONS(1-4)	KG/HA	13
WHYS	P	LENGTH OF PLANNED HAY SUPPLEMENTATION PERIOD	WEEK	05
WIW1		SWITCH - WEANERS IN WHEAT SUBSECT(1-4) OR NOT(1,0)		11
WLAM		LIVE-WEIGHT OF LAMB	KG/HEAD	11
WLW	P	WEIGHT OF LAMBS AT WEANING	KG/HA	05
WLWCH		WEANER LIVE-WEIGHT CHANGE	KG/HEAD/DAY	11
WOOL		AMOUNT OF WOOL SHORN	KG/HA/YEAR	09
WOOLSH	P	WOOL YIELD PER SHEEP	KG/HEAD	05
WPAST	P	MINIMUM PASTURE FOR WEANER GRAZING	KG/HA	05
WSTS	P	LENGTH OF PLANNED STRAW SUPPLEMENTATION PERIOD	WEEK	05
WTIM		WEANING DATE	WEEK(YTIME)	08
WTPG	P	AVAILABLE WATER THRESHOLD FOR POTENTIAL GROWTH	MM	05
WWNR		LIVE-WEIGHT OF WEANER	KG/HEAD	11
		Y Y Y		
YM		VECTOR FOR STORING END OF YEAR SUMMARIES	-	15
YSEL	P	YEAR SELECTOR IN MULTIYEAR TWOVAR FNS (UNOPERATIVE	-	05
YTIME		WEEKS AFTER BEGINNING OF BUDGET YEAR	WEEK	06
		Z Z Z		
ZAINC		SWITCH - TO EMPTY INTEGRAL AINCRE		11
ZERO	P	ZERO CONDITION WEIGHT OF BREED	KG/HEAD	05
ZW		SWITCH - WEANERS EXIST(1) OR NOT (0)	-	11

Appendix III

ALPHABETICAL LIST OF THE MIGDA SYSTEM MODEL

This alphabetical list of the program statements provides a simple means of finding the precise coded definition of any variable defined in the model. Statements that do not define a variable (e.g. functions, parameters, comments) have been omitted.

```
    ****     MIGDA SYSTEM MODEL STATEMENT DICTIONARY        ****
             =========================================

ALPHABETICAL LIST OF MODEL STATEMENTS IN THE MIGDA SYSTEM MODEL.
THE PURPOSE OF THIS STATEMENT DICTIONARY IS TO ENABLE THE READER
TO FIND WITH EASE THE CSMP CODED DEFINITION OF ANY VARIABLE THAT
APPEARS IN THE MIGDA SYTEM MODEL.   THE COLUMN OF FIGURES ON THE
RIGHT-HAND SIDE IS THE LINE NUMBER OF THE STATEMENT IN THE MODEL
LISTING. A FULL MODEL LISTING IS PROVIDED IN ANOTHER APPENDIX.
    THE FOLLOWING STATEMENTS FROM THE MODEL LISTING DO NOT APPEAR
    IN THIS DICTIONARY- FUNCTION, PARAMETER, PROCEDURE, AND ARRAY
    DEFINITION STATEMENTS, 'IF' AND 'DO' STATEMENTS, COMMENTS AND
    STATEMENT CONTINUATION LINES, AND A FEW OTHER STATEMENTS THAT
    DO NOT ACTUALLY DEFINE A MODEL VARIABLE THAT THE READER WOULD
    CONCEIVABLY WISH TO REFERENCE.


ACT = FCNSW(XTIM-YTIME,0.,1.,0.)                                          00000093
AGEW = AMAX1(0.,YTIME-LTIM)                                               00000713
AINCRE = INTGRL(IAINE,(INGWE-(INGWE+AINCRE-4.)*HARV1-AINCRE*ZAINC)/DELT)00000757
AINCRW = INTGRL(IAINW,(INGWW-(INGWW+AINCRW-4.)*HARV1-AINCRW*ZAINC)/DELT)00000758
ANBAL=INTGRL(INBAL,GRINC-COST+(INSW(ANBAL,-LOANR/52.,DEPOSR/52.))*ANBAL)00000423
ASMWK = INTGRL(IAS,ASM - ASMWK*EGS/DELT)                                  00000388
AUX1 = INSW(ASMWK-8.,DML2,DML3)                                           00000811
AUX2 = INSW(GRAIN/((DV+GV)+NOT(GV+DV))-THGSR,1.,0.)*TUDRY                 00000078
AVHAY = HSTAK/(NEWES*7.+NOT(NEWES))*DIGH                                  00000641
AVSTR = SSTAK/(NEWES*7.+NOT(NEWES))*DIGS                                  00000642
AVW = INTGRL(AVWI,(MGR-GRV)*M/1.E4-AVW*EVBS*D7*(1.+ ASMWK/12.))            00000038
BALHC = INTGRL(IBHY,BALHY-BALHC*NWYR/DELT)                                00000782
BALHY = FRW  *(1.-HLOSS)*(BLHY1+BLHY2+BLHY3+BLHY4)/(4.*DELT)              00000777
BALSC = INTGRL(IBST,BALST-BALSC*NWYR/DELT)                                00000781
BALST =  FRW  *(BLST1+BLST2+BLST3+BLST4)/(4.*DELT)                        00000773
BAYL = INSW(DVW*B-T,0.,INSW(E-DVW*FRW,1.,0.))*BS                          00000814
BLHY = D2BH*HAY*(AMAX1(0.,GV-500.)+AMAX1(0.,DV-1000.))/DELT               00000076
BLST=D2BS*DV*B*BAYL                                                       00000075
BRDFR = INTGRL(IBRF,BREEDF*ECON*JOIN*HORM /DELT-BRDFR*WEAN/DELT)          00000513
BS  =  MACT(ST)                                                           00000405
BSWEEK=HWEEK+W2BS                                                         00000177
CHARH =(RAKE*FRW  +BALE*BALHC)*BALHC/(BALHC+NOT(BALHC))                   00000497
CHARS = (RAKE*FRW+BALE*BALSC)* BALSC/(BALSC+NOT(BALSC))                   00000496
CHARW =  FRWHT*FHC+AMAX1(0.,VHC*(GRAINH-250.))                            00000494
CHGD=INSW(GVP-DVP,0.,1.)                                                  00000977
CONCF = INTGRL(ICF,CONUSE-(CONCF/DELT+CONUSE)*NWYR)                       00000787
CONUSE = (SUPPEC*NEWES+SUPPLC*NLAMS+SUPPWC*NWNRS)*7./DIGC                 00000788
COST =(CPAST+CSUPP+INEWE*(CLPE+FXVPE*BREEDF+DEPOSR +  ...                 00000498
COTW = INTGRL(ICW,SUPECW*NEWES*7./DIGCW-NWYR*COTW/DELT)                   00000792
CPAST = (FXPC+CFERT*AFERT+CPSEED*IGVP)*FRPAST                             00000493
CRITGV = (GVSAFE+GVEQ)/2.                                                 00000607
CSUPP = CONCF*PRCONC+COTW*PRCOTW                                          00000495
CTIM = WTIM+1.                                                            00000410
CTIME = INSW(WEEK-SWEEK,52.-(SWEEK-WEEK),WEEK-SWEEK)                      00000098
CULL =MACT(CTIM)                                                          00000400
CULLS = INEWE*CULLR                                                       00000234
DEFER = INTGRL(IDEF,DEF)                                                  00000590
DEFERR=INSW(-AINCRE,1.,DEFER)                                             00000577
DIGD= INSW(-EGSD,LIMIT(LDD,HDD,HDD-(HDD-LDD)*(YTIME-ESTIM)/HQDPP),  ...   00000575
DIGDME =(KMNT*WEWE**0.75 ) ...                                            00000569
DIGDML = KMNT*WLAM**0.75                                                  00000699
DIGPE = (EGPI*DIGG+EDPI*DIGD)/(EWINT +NOT(EWINT))                         00000574
DMCPW = INTGRL(IDMC,(INGP+INDP)*FRPAST + (INGW1+INDW1+INGW2+INDW2+     ...00000796
DONE = INTGRL(0.,(AKT-DONE*MT)/DELT)                                      00000103
DPX = AMAX1(GRW1*DVW1,GRW2*DVW2,GRW3*DVW3,GRW4*DVW4)                      00000952
DPX = AMAX1(0.,DPX)                                                       00000984
DPX = DPX-RZW(N)*EWOWN                                                    00000969
DPX = DVWH(N)*WGRZW(N)                                                    00000960
DPX = DVP-RZP*EWOWN*(1.-CHGD)                                             00000981
DRGV=(GV/DELT-ING)*7.*AMAX1(SENESC,DRYR-SM*DRYR*10.)+HARV1*GV*(1.-TFVS)  00000043
DV = INTGRL(ID,NDVR*(1.-PLOW)+((1.-G+D2BH )*GRAIN-DV*PLOW)/DELT)          00000056
DVS = INSW(GV-1.,0.,INSW(ASMWK-25.,INSW(YTIME-ETIME,1.,0.),0.))           00000042
DVW=(DVW1+DVW2+DVW3+DVW4)/4.                                              00000842
D2BH = D2BP*INSW(-HAY,INSW(GV+DV-2000.,0.,INSW(GV-1000.,0.,AUX2)),0.)     00000077
D7 = DELT*7.                                                              00000130
E = INEWE*10.5*(PTIM-ST)/(1.+WASTE)                                       00000288
ECON = AFGEN(EWCONB,EWCON)                                                00000514
EDPI = EDPI1*DEFERR                                                       00000572
EDPI1 = AMIN1(AMAX1(0.,PEDPI-EGPI),DPE/(7.*DELT))                         00000573
```

```
EGPI = EGPI1*DEFERR                                                             00000565
EGPI1= AMIN1(LIMIT(0.,PGCXE,GPE*EGEF*(1.+INSW(AGEW-4.,0.,1.)*LER         ...  00000563
EGS = AND(PSM-0.01,0.01-SM)                                                     00000419
EGSD,ESTIM = CDX(EGS,GERM)                                                      00000413
EPTIM = CT(EPWEEK)                                                              00000352
EWCH = EWCH*15.481*0.62/(20.*0.8)                                               00000557
EWCH=EWFB*.55-LER*.62*(LMWCH/.77+KMNT*WLAM**.75)                                00000555
EWCON =(LIMIT(0.,5.,(WEWE-ZERO)*5./(MXBRW-ZERO))-LAM*0.2)                       00000552
EWFB = (EWINT*DIGPE-DIGDME+SUPPE)                                               00000561
EWINT = EGPI+EDPI                                                               00000562
EWTIM = CT(EWWEEK)                                                              00000353
EXGR = AMAX1(WEGR,LIMIT(0.,1.,AVW/WTPG)*PRGR*D7)                                00000036
FRGWHT = INTGRL(IFGW,(FRW/4.*INCFGW-FRGWHT*NWYR)/DELT)                          00000763
FRW = 1. -FRPAST                                                                00000276
FRWHT = (1.-FRPAST)-FRGWHT                                                      00000762
FR1 = INSW(-PS,FRPAST,(FR+NOT(FR))/4.)                                          00000045
G = 1.-AMIN1(1.,GRE+GRW)                                                        00000056
GERM = AND(0.01-PSM,SM-0.01)                                                    00000418
GERMD,GTIM = CDX(GERM,NWYR)                                                     00000414
GHARV = INTGRL(IH,GRHAR-GHARV*NWYR/DELT)                                        00000059
GPX = AMAX1(GRW1*GVW1,GRW2*GVW2,GRW3*GVW3,GRW4*GVW4)                            00000951
GPX = AMAX1(0.,GPX)                                                             00000983
GPX = GPX-RZW(N)*EWOWN                                                          00000961
GPX = GVWH(N)*WGRZW(N)                                                          00000963
GPX = GVP-RZP*EWOWN*CHGD-(1.-CHGD)*MNRZ                                         00000980
GRAIN = INTGRL(IS,GRGR-GRHAR-SDL-GSEED-(GRAIN/DELT-SDL)*(PLOW+1.-G))            00000053
GRAINH=FRW  *(WHARV1+WHARV2+WHARV3+WHARV4)/4.                                   00000437
GRGR = GRV*TRG/(1.-TRG)*INSW(GRAIN-GV-DV,1.,0.)*G+TFVS*GV*EGS*G/DELT            00000055
GRHAR = (1.-AMIN1(1.,GRE+GRW))*HARV*FRHARW*GRAIN/DELT                           00000057
GRINC =(PRLAM*NLAMSL*WLAM*SELLL+PRWNR*NWNRSL*WWNR*SELLW+PREWE*REPL ...          00000432
GRV = INSW(GV-1900.,EXGR*GV,LINGR)*DVS*(1.-TRG)                                 00000035
GRZN = INSW(EIW+WIW-1.,0.,1.)                                                   00000060
GSEED=GERM*AMAX1(MINSS,GRAIN)*(1.-FRG)/DELT+(GRGR+GRAIN/DELT)*D28H              00000054
GV = INTGRL(IG,FRG*GERM*(IGV+GRAIN)/DELT+NGRV-HARV1*(GV/DELT+NGRV))             00000028
GVEQ = HS*RZP/((HS-RGRPE)+NOT(HS-RGRPE))                                        00000606
GVSAFE = PGCXE*(NEWES/FRPAST)/(RGRPE+NOT(RGRPE))                                00000603
GVSAT = PGCXE/EGEF+RZP                                                          00000602
GVW=(GVW1+GVW2+GVW3+GVW4)/4.                                                    00000841
G1 = WGRZW(1)                                                                   00000940
G2 = WGRZW(2)                                                                   00000941
G3 = WGRZW(3)                                                                   00000942
G4 = WGRZW(4)                                                                   00000943
HARV=INSW(-HARV1,INSW(WG-MINGH,0.,1.),0.)                                       00000406
HARV1= MACT(HTIM)                                                               00000404
HAY = MACT(HYTIM)                                                               00000403
HORM = INSW(EWCON-2.0,1.,HORMT)                                                 00000515
HS = NEWES*EGEF                                                                 00000605
HSELL = INSW(MXHST-HSTAK,HSTAK-MXHST,0.)*PLOW                                   00000773
HSTAK = INTGRL(IHST,BALHY-SUPPEH*NEWES*7./DIGH-HSELL/DELT-   ...                00000775
HTIM = CT(HWEEK)                                                                00000354
HYTIM = CT(HYWEEK)                                                              00000358
HYYR =INTGRL(1.,UPDHY/DELT)                                                     00000447
IGVR = INSW(-TRG,120./1000.*GRV,0.)                                             00000050
INCFGW =          INSW(NOGEF-ASMWK,INSW(-FRWHT,INGWW+INGWE,0.),0.)              00000764
IND = GRZN*AMIN1(DV/DELT,(EDPI*EIW*NEWES*7.+WDPI*WIW*NWNRS*7.)/FR1)             00000069
ING = GRZN*AMIN1(GV/DELT,(EGPI*EIW*NEWES*7.+WGPI*WIW*NWNRS*7.)/FR1)             00000044
IWLAM = AFGEN(BIRWT,LAMFR)*AFGEN(ECONLM,EWCON)*LAM                              00000688
JOIN = MACT(JTIM)                                                               00000398
JTIM = CT(JWEEK)                                                                00000350
LAM = MACT(LTIM)                                                                00000399
LAMFR = BRDFR*ECON                                                              00000512
LDTIM = CT(LDWEEK)                                                              00000357
LER = NLAMS/NEWES                                                               00000568
LGTIM =  CT(EGWEEK)                                                             00000351
LINGR = MXGR*D7*AMAX1(SM,LIMIT(0.,1.,AVW/WTPG))                                 00000037
LMWC = INSW(EWCON-1.,LIMIT(0.,0.350,0.35*EWFB/(PGCXE*DIGG-DIGDME)),...          00000691
LMWCH = INSW(-D2SUPL,0.35,LMWC)*AFGEN(LGRT,LER   )    *NLAMS/      ...          00000689
LOSS = (DV/DELT-IND)*LOSS1*7.+INSW(DV/DELT-IND*(1.+WASTE),0.,WASTE*IND)         00000068
LOSS1 = INSW(-EGS,DMLOM/(7.*DELT),INSW(-ASMWK,AUX1,DML1))                       00000810
LSURV = AFGEN(LAMRT,BRDFR)                                                      00000516
LTIM = CT(LWEEK)                                                                00000349
LWEEK=INSW(52.-(JWEEK+21.),(JWEEK+21.)-52.,JWEEK+21.)                           00000175
MACRO ACT = MACT(XTIM)                                                          00000092
MACRO CTIME = CT(WEEK)                                                          00000097
MACRO DONE,XTIM1= CDX(AKT,MT)                                                   00000102
MGR = DERIV(IMGR,AFGEN(MGCT,YTIME+0.5*DELT))                                    00000039
MINW4G=10.*PGCXE*NEWES/(FRW/4.)                                                 00000735
MONTH = AFGEN(MONTT,RTIME)                                                      00000374
MXDMIW = AFGEN(CXWT,AGEW)                                                       00000712
MXHST = 7.*1.5*INEWE*WHYS                                                       00000296
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```
MXSST= 7.*1.*INEWE*WSTS                                                 00000295
NDVR = DRGV-LOSS-IND-BLST- AMAX1(0.,HAY*(DV-1000.)*D2BH/DELT)           00000067
NEWES = INTGRL(INEWE,(NWNRS*PLOW-REPL*CULL )/DELT-EMORT*NEWES/52.)      00000509
NGRV = GRV-DRGV-ING-AMAX1(0.,HAY*(GV-500.-DRGV-ING)*D2BH/DELT)          00000029
NLAMS = INTGRL(INL,(LAM*NEWES*(1.-CULLR)*LAMFR*LSURV-WEAN*NLAMS)/DELT)  00000511
NLAMSL = SELLL*AMAX1(0.,NLAMS-REPL1)                                    00000517
NWNRS =INTGRL(INW,((REPL1+(NLAMS-REPL1)*RAISW )*WEAN-AMAX1(0.,NWNRS- ...00000540
NWNRSL = AMAX1(0.,NWNRS-REPL)                                           00000440
NWYR = 1.-YTIME/(YTIME+NOT(YTIME))                                      00000372
NYR=1.+YSEL+TIME/52.-AMOD(TIME,52.)/52.                                 00000380
P = INTGRL(IP,GRV/(1.-TRG)*(1.-NWYR)-NWYR*P/DELT)                       00000041
PDCXE =1.5+AMAX1(AMIN1(.2,LER*0.1),LER*MXDMIW*DIGD/DIGG)                00000567
PEDPI = LIMIT(0.,PDCXE,DPE*EGEF*(1.+INSW(AGEW-4.,0.,1.)*LER*WLAM/WEWE)) 00000571
PGCXE = 2.+AMAX1(AMIN1(1.,LER*0.5),LER*MXDMIW)                          00000566
PLOW = MACT(PTIM)                                                       00000402
PREWE = AFGEN(PRET,YTIME)*AFGEN(EWCONS,EWCON)                           00000443
PRHAY = AFGEN(PRHT,YTIME)*HYYR                                          00000444
PRLAM = AFGEN(PRLT,YTIME)*AFGEN(LWRT,WLAM)                              00000441
PRSTR = AFGEN(PRST,YTIME)*STYR                                          00000445
PRWNR = AFGEN(PRLT,YTIME)*AFGEN(LWRT,WWNR)                              00000442
PSM = DELAY(5,DELT,SM)                                                  00000417
PTIM = CT(PWEEK)                                                        00000355
PV=INTGRL(IPV,SM*750.-HARV1*PV/DELT)                                    00000389
REPL = INTGRL(IREP,(REPL1*WEAN-REPL*PLOW)/DELT)                         00000519
REPL1 = AMIN1(INEWE*CULLR,NLAMS)                                        00000518
RGRPE = (GRVP/7.)/(GVP+NOT(GVP))                                        00000604
RTIME = AMOD(TIME+SWEEK,52.)                                            00000373
RZ = INTGRL(IRZ,IGVR-(IGVR+(RZ-MNRZ)/DELT)*GERM-RZ*PLOW/DELT)           00000049
SDL = INSW(YTIME-(HTIM+1.),0.,GRAIN*SLWK)                               00000058
SELLG = MACT(HTIM+1.)                                                   00000473
SELLL = WEAN*(1.-RAISW)                                                 00000474
SENESC = INSW(ASMWK-6.,0.,SENES)                                        00000812
SHEAR = MACT(SHTIM)                                                     00000401
SHTIM = CT(SHEARW)                                                      00000356
SM = AFGEN(SMT,YTIME)                                                   00000382
SOLDW,SWTIM = CDX(SELLW,NWYR)                                           00000412
SSTAK = INTGRL(ISST,BALST-SUPPES*NEWES*7./DIGS    -STSELL/DELT-   ...   00000771
ST    =   CT(BSWEEK)                                                    00000359
STSELL = INSW(MXSST-SSTAK,SSTAK-MXSST,0.)*PLOW                          00000774
STYR =INTGRL(1.,UPDST/DELT)                                             00000446
SUPECW = SUPPES-1.*DIGS                                                 00000669
SUPECW = SUPPES-AVSTR+SUPECW                                            00000675
SUPECW = 0.25*DIGCW                                                     00000673
SUPL = D2SUPL*INSW(EGPI-PGCXE*0.9,2.*DIGDML*(1.-AMAX1(0.,(EGPI-  ...    00000697
SUPPE = SUPPES+SUPPEH+SUPPEC+SUPECW                                     00000681
SUPPEC = SUPECW-0.25*DIGCW                                              00000672
SUPPEC = SUPPEH-1.5*DIGH                                                00000654
SUPPEC = SUPPEH-AVHAY+SUPPEC                                            00000657
SUPPEH = 1.5*DIGH                                                       00000655
SUPPEH = AVHAY                                                          00000658
SUPPEH = DIGDME*(1.+FLUSH)-EGPI*DIGG-EDPI*DIGD                          00000651
SUPPES = DIGDME-EGPI*DIGG-EDPI*DIGD+(LMWCH/0.77+KMNT*WLAM**.75)*LER     00000666
SUPPES = 1.*DIGS                                                        00000670
SUPPES = AVSTR                                                          00000676
SUPPLC = INSW(YTIME-(LTIM  +4.),0.,INSW(YTIME-WTIM  ,SUPL,0.))          00000696
SUPPWC= D2SUPW*AMIN1(MXWSUP,WDPDF,AMAX1(0.,(KMNT*WWNR**0.75+   ...      00000707
TRG = INSW(YTIME-23.,INSW(ASMWK-13.,0.,INSW(ASMWK-15.,ETF,LTF)),LTF)    00000046
TUDRY = INSW(SM-0.2,1.,0.)                                              00000813
UPDHY = INSW(PP4   -3000.,HPINC,INSW(PP4   -6000.,-HYYR+1.,   ...       00000456
UPDST = INSW(PP4   -3000.,SPINC,INSW(PP4   -6000.,-STYR+1.,   ...       00000453
WDPDF = AMAX1(0.,MXDMIW - WGPI - WDPI)*ZW                               00000709
WDPI = AMIN1(DPW/(7.*DELT),AMAX1(0.,LIMIT(0.,MXDMIW,DPW*EGEF)-WGPI))*ZW 00000710
WEAND,WTIM  = CDX(WEAN,PLOW)                                            00000411
WEGR = EXP(RGR*SM*DELT*7.) - 1.                                         00000809
WEWE=INTGRL(IWEW,EWCH*7.-((LAM*IWLAM*LAMFR*AFTBF)+PLOW*NWNRS ...        00000550
WFBAL = WGPI*DIGG+WDPI*DIGD+SUPPWC*DIGC-KMNT*WWNR**0.75                 00000706
WG=(WG1+WG2+WG3+WG4)/(4.*(FRWHT+NOT(FRWHT))/(FRW+NOT(FRW)))             00000407
WGPI = AMIN1(GPW/(7.*DELT),LIMIT(0.,MXDMIW,GPW*EGEF))*ZW                00000711
WGRZW(I) = AMAX1(0.,AMIN1(1.,AINCR -(I-1)))                             00000938
WLAM=INTGRL(IWL,IWLAM/DELT+LMWCH*7.*(1.-WEAN)-WEAN*WLAM/DELT)           00000687
WLWCH = WFBAL*0.62*AFGEN(ECWT,WWNR)                                     00000705
WOOL = SHEAR*NEWES*WOOLSH                                               00000433
WWNR = INTGRL(IWW,WLAM*  WEAN/DELT+WLWCH*7.*(1.-PLOW)-PLOW*WWNR/DELT)   00000703
W1 = WW(1)                                                              00000993
W2 = WW(2)                                                              00000994
W3 = WW(3)                                                              00000995
W4 = WW(4)                                                              00000996
XTIM1 = INTGRL(52.,(AKT*(YTIME-52.)-(XTIM1-52.)*MT)/DELT)               00000104
YM(K1)=MMV(K1)                                                          00000897
YTIME = AMOD(TIME,52.)                                                  00000371
ZP = 1.-WGRZW(1)                                                        00000947
ZW=INSW(-NWNRS,1.,0.)                                                   00000714
```

Appendix IV

PROGRAM TO CALCULATE SMT FUNCTION THAT IS SUBSEQUENTLY USED IN THE MIGDA SYSTEM MODEL

```
C      SM CALCULATION
C     --------------------
       DIMENSION DY(20),V(20),ADD(12),R(20),VC(35),SM(35),COT(10),GR(35),
     2GV(35),IJ(35)
       DATA ADD/92.,123.,151.,182.,212.,243.,273.,304.,335.,0.,31.,61./
C
C
       DO 200 JJJ=1,20
       DO 90 I=1,20
       DY(I)=0.
       V(I)=0.
       R(I)=0.
   90 CONTINUE
       DO 91 I=1,35
       VC(I)=0.
       SM(I)=0.
       GR(I)=0.
       GV(I)=0.
   91 CONTINUE
       READ 14,COT
   14 FORMAT(10A4)
       N=0
       DO 1 I=1,20
       READ 13,DAY,MONTH,V(I)
   13 FORMAT(F3.0,I2,F8.2)
C   V=OBSERVED TOTAL GREEN+DRY BIOMASS
       IF(DAY.GT.31)GO TO 17
C
C   CALCULATE JULIAN DAY  (DY)
C
       DY(I)=DAY+ADD(MONTH)
       N=N+1
    1 CONTINUE
C
C   CALCULATE EXP AND LIN GROWTH RATES FOR GREEN AND DRY BIOMASS (R)
C
   17 NN=N-1
       DO 2 I=1,NN
       RE=ALOG(V(I+1)/V(I))/(DY(I+1)-DY(I))
       RL=(V(I+1)-V(I))/(DY(I+1)-DY(I))
       IF(V(I+1).LT.200.)R(I)=RE
       IF(V(I).GE.200.)R(I)=RL
       IF(V(I).LT.200..AND.V(I+1).GE.200.)GO TO 3
       GO TO 2
    3 IF(200.-V(I).GE.V(I+1)-200.) R(I)=RE
       IF(200.-V(I).LT.V(I+1)-200.) R(I)=RL
    2 CONTINUE
       R(N)=R(NN)
C
C   N=NO OF DATA SETS
C   L=NO OF EFFECTIVE WEEKS
C   J=DATA COUNTER
C
C   VALUES WEEKLY GREEN+DRY BIOMASS
C
       L=(DY(N)-1)/7+2
       J=1
       DO 5 I=1,L
       DT=I*7+1-DY(J)
       M=(DY(1)-1)/7
       IF(I.LE.M)GO TO 6
    9 DT=I*7+1-DY(J)
       M1=(DY(J)-1)/7
       M2=(DY(J+1)-1)/7
       IF(J.EQ.N)M2=M1+1
       IF(I.GT.M1.AND.I.LE.M2)GO TO 7
       J=J+1
       IF(J.EQ.N+1)GO TO 16
       GO TO 9
    7 IF((V(J).GT.200.).OR.(200.-V(J).LT.V(J+1)-200.))GO TO 8
       GO TO 4
    6 VC(I)=V(J)*EXP(R(J)*DT)
       GO TO 5
C   VC=CALCULATED TOTAL GREEN+DRY BIOMASS
    4 VC(I)=V(J)*EXP(R(J)*DT)
       GO TO 5
    8 VC(I)=V(J)+R(J)*DT
    5 CONTINUE
```

```
C
C      SM GROWTH RATE REDUCTION FUNCTION FOR GREEN+DRY BIOMASS
C
   16 LL=L-2
      DO 10 I=1,LL
      IF(VC(I).GE.200.)GO TO 11
      IF(VC(I).LT.200..AND.VC(I+1).GE.200.)GO TO 12
      SM(I)=10.*ALOG(VC(I+1)/VC(I))/7.
      GO TO 10
   11 SM(I)=(VC(I+1)-VC(I))/(7.*20.)
      GO TO 10
   12 SM(I)=(10.*ALOG(VC(I+1)/VC(I))/7.+(VC(I+1)-VC(I))/(7.*20.))/2.
   10 CONTINUE
C
      PRINT 15,COT
   15 FORMAT(1H1,50X,10A4/53X,38('=')//)
      PRINT 103
  103 FORMAT(10X,'ORIGINAL DATA'/8X,17('-')/3X,'NO',7X,'JULIAN DAY',8X,
     C'V',13X,'R'//)
      DO 21 I=1,N
      PRINT 101,I,DY(I),V(I),R(I)
  101 FORMAT(1X,I4,5X,F10.0,5X,F10.2,5X,F12.8)
   21 CONTINUE
      PRINT 102
  102 FORMAT(//10X,'CALCULATION FOR GREEN AND DRY BIOMASS'/8X,37('-')/2X
     C,'WEEK',11X,'VC',10X,'SM'//)
      DO 20 I=1,LL
      II=I+1
      PRINT 100,II,VC(I),SM(I)
  100 FORMAT(1X,I5,5X,F10.2,5X,F7.3)
   20 CONTINUE
C
C
C     GR=GROWTH RATE CALCULATED ON GREEN BIOMASS ONLY
C     DR=DEATH RATE OF GREEN VEG.
C     DR=0.01 WHEN SM GT 0.9
C     DR=0. WHEN GV LT 50.
C     GV=GREEN VEGETATION
C
C
C    CALCULATE GV FROM D(VC)/DT AND  APPROX DR=F(SM)
C    ITERATE K TIMES AND HOPE FOR CONVERGENCE.
C
      GV(1)=VC(1)
      DO 40 K=1,3
      DO 30 J=1,LL
      DR=AMAX1(0.01,0.1-SM(J))
      IF(VC(J).LE.50.)DR=0.
      GV(J+1)=VC(J+1)-VC(J)+GV(J)*(1.-DR*7.)
   30 CONTINUE
      DO 31 J=1,LL
      IF(GV(J).GE.200..OR.200.-GV(J).LT.GV(J+1)-200.)GO TO 32
      GR(J)=ALOG((GV(J)+VC(J+1)-VC(J))/GV(J))/7.
      SM(J)=10.*GR(J)
      GO TO 31
   32 GR(J)=(VC(J+1)-VC(J))/7.
      SM(J)=GR(J)/20.
   31 CONTINUE
      PRINT 104
  104 FORMAT(//10X,'CALCULATION FOR GREEN VEGETATION'/8X,36('-')/2X,'WEE
     CK',7X,'GV',12X,'GR',12X,'SM',14X,'K'/)
      DO 18 I=1,LL
      II=I+1
      PRINT 106,II,GV(I),GR(I),SM(I),K
  106 FORMAT(1X,I5,5X,F6.2,5X,F8.3,5X,F10.3,13X,I1)
   18 CONTINUE
   40 CONTINUE
      PRINT 107
  107 FORMAT(///1X,'FUNCTION  SMT,1. = 0.,0.,                          ... ')
      DO 50 I=1,LL
   50 IJ(I)=I+1
      PRINT 108,(IJ(I),SM(I),I=1,LL)
  108 FORMAT(1X,6(I2,',',F5.3,',',3X),' ...')
      ALL = LL+2
      PRINT 109,ALL
  109 FORMAT(1X,F2.0,',0.,  52.,0.')
  200 CONTINUE
      STOP
      END
```

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הבעת תודה

עבודה זו היא חלק מפרוייקט מחקר משותף ישראלי-הולנדי בנושא: ייצור, בכוח ובפועל, של מרעה באזורים צחיחים-למחצה. הפרוייקט מומן על-ידי ה-DTH של משרד החוץ ההולנדי והשתתפו בו חוקרים ממינהל המחקר החקלאי, וכן חוקרים מהמחלקה לבוטניקה של האוניברסיטה העברית בירושלים, מהמחלקה לאקולוגיה תיאורטית של גידולי שדה באוניברסיטה החקלאית של ואכנינגן, ומ-CABO ואכנינגן.

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מודל לניתוח שיטות ממשק במערכת פלחה-מרעה כבשים, בנגב הצפוני

נ"ג זליגמן*, ר"ו בנימין*, ע' איל**

ת ק צ י ר

המודל המובא בפרסום זה מתאר מערכת משקית, המורכבת משדות חיטה ומשדות מרעה לצאן. משדות החיטה מופקים גרעינים וקש, ובתנאים מסויימים - שחת-חיטה או מרעה. עדר הצאן יוצר טליות לתחלופה ובשר וצמר - לשיווק. מטרתו של מודל זה היא לנתח אופציות ממשק שונות, הנוגעות ליחסי השטח חיטה-שטחי מרעה, למספר הכבשים המיטבי לשטח, לשיטות רעייה והזנה משלימה ולעונות הרבייה השונות. המודל מציג אמות-מידה כלכליות וביולוגיות, אשר לפיהן אפשר לקבוע את טיבן של שיטות הניהול השונות.

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---

* המחלקה למרעה, המכון לגידולי שדה וגן

** המחלקה לצאן, המכון לחקר בעלי-חיים

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מינהל המחקר החקלאי
המכון לגידולי שדה וגן * המכון לחקר בעלי-חיים

מודל לניתוח שיטות ממשק במערכת פלחה-מרעה כבשים בנגב הצפוני

ב"ג זליגמן, ר"ו בנימין, ע' איל

פרסום מיוחד מס' 207

המחלקה לפרסומים מדעיים
מרכז וולקני, בית-דגן
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מינהל המחקר החקלאי

המכון לגידולי שדה וגן   המכון לחקר בעלי-חיים

מודל לניתוח שיטות ממשק במערכת פלחה-מרעה כבשים בנגב הצפוני

נ"ג זליגמן, ר"ו בנימין, ע' איל

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