2. RATE OF WORK

Rate of Work or Farm work capacity (or efficiency) varies by equipment capacity, operator ability, and field and crop conditions.
Work abilities of machine or manual for field work, will be expressed by hours per area, or area per hour, which is called as area capacity.
Work abilities of machine or manual for stationary work, will be expressed by hours per weight, or weight per hour, which is called as material capacity.

In this textbook, Effective Field Capacity is commonly used as hectares or tons per an hour, in a block of field or a unit of material. In the case of farm work by machine, Effective Field Capacity will be expressed the value on a set of machine with operators. In manual farm work, Effective Field Capacity will be expressed the value by a worker.
Also, Work Capacity is defined the reciprocal of Effective Field Capacity, like as hours per a hectare or a ton.

2-1. Effective Field Capacity

Effective Field capacity is the actual rate of land or crop processed in a given time. Effective Field capacity is called as field capacity simply.

2-1-1.Effective Field Capacity for field work

$$EFC = A / T \qquad \text{Eq. 2-1-1}$$

$$WC = 1 / EFC = T / A \qquad \text{Eq. 2-1-2}$$

Where,

symbol	term	unit	Example
EFC	Effective Field Capacity	ha/h	0.5
T	Total field time required a work	h	2.0
A	Field area	ha	1.0
WC	Work Capacity	h/ha	2.0

a) Total time required a farm work

Field time is in ASAE defined like as; the time a machine spends in the field measured from the start of functional activity to the time the functional activity for the field is completed.

b) Field area

Field area for effective field capacity is a field block as minimum unit.

c) Example

Standard value of effective field capacity in appendix.(Table A-211., A-212., A-213) Refer to appendix\FM-211-workrate.XLS

Exercise. 2-1, 2-2, 2-3

2-1-2.Effective Field Capacity for stationary work etc.

EFC = (P / Y) / T **Eq. 2-1-3**

WC = T / (P / Y) **Eq. 2-1-4**

Where,

symbol	term	unit	Example
EFC	Effective Field Capacity	ha/h	0.06
T	Total time required a farm work	h	2.0
P	Weight of production, grain etc.	t	0.6
Y	Yield or amount per hectare	t/ha	5.0
WC	Work Capacity	h/ha	16.7

See appendix\FM-211-workrate.XLS

Exercise. 2-4

2-1-3.Theoretical Field Capacity

Theoretical Field Capacity is the rate of performance obtained if a machine performs its function 100% of the time at a given operating speed using 100% of its theoretical width. (Refer to ASAE S495)

a) Theoretical field capacity

The theoretical field capacity will be led from the following equation.

TFC = Wt * Vt * K **Eq. 2-1-5**

TFC = Wt * Vt * 0.1 **Eq. 2-1-5a**

Where

symbol	term	Unit: 1	Unit: 2
TFC	Theoretical field capacity	ha/h	ha/h
Wt	Theoretical operation width	m	m
Vt	Theoretical operation speed	km/h	m/s
K	Constant	0.1	0.36

We normally use unit-1 system; therefore theoretical field capacity is shown as Eq. 2-1-5a.

TFC = A / Tt **Eq. 2-1-6**

Where, Tt = 10 * A / (Wt * Vt)

Example: See next table

Exercise. 2-6

b) Calculated field capacity

Calculated field capacity is obtained by actual operating time (Ta) for the area (A), or by actual width (Wa) and actual speed (Va) as follows, which value is often used as theoretical field capacity.

(i) Actual operation width (effective operation width): Wa

This is the actual operation width in the field, obtained by the width of the field divided by the number of actual strokes in operation.

CFC (ha/h) = A (ha) / Ta (h) **Eq. 2-1-7**

Where, Ta = 10 * A / (Wa * Va)

CFC (ha/h) = Wa (m) * Va (km/h)* 0.1 **Eq. 2-1-7a**

Where,

symbol	term	Unit	Example
EFC	Effective Field Capacity	ha/h	0.30
TFC	Theoretical field capacity	ha/h	0.54
CFC	Calculated field capacity	ha/h	0.40
T	Total time required a farm work (Total operating time)	h	1.0
Tt	Theoretical operating time	h	0.56
Ta	Actual operating time	h	0.75
A	Field area	ha	0.30
Wt	Theoretical operation width	m	1.8
Vt	Theoretical operation speed	km/h	3.0
Wa	Actual operating width	m	1.6
Va	Actual operating speed	km/h	2.5

Refer to fm-215.xls

2-1-4.Field Efficiency: (or Functional Efficiency)

a) Field Efficiency

Actual effective field capacity is different from theoretical field capacity. For example, actual field operation is including loss times of turning, feeding etc. Therefore, actual effective field capacity might be smaller than theoretical field capacity.
The following equation shows to find Field Efficiency.

fe = EFC / TFC **Eq. 2-1-8**

FE = EFC / TFC * 100 **Eq. 2-1-8a**

Also, calculated field efficiency is obtained from Eq. 2-1-1 and Eq. 2-1-7 as follows.

fe_c = EFC / CFC = Ta / T **Eq. 2-1-9**

FE_C = EFC / CFC * 100 = Ta / T * 100 **Eq. 2-1-9a**

Where,

symbol	term	unit
EFC	Effective Field Capacity	ha/h
TFC	Theoretical Field Capacity	ha/h
CFC	Calculated Field Capacity	ha/h
fe	Field Efficiency in decimal	
fe_c	Calculated Field Efficiency in decimal	
FE	Field Efficiency in percentage	%
FE_C	Calculated Field Efficiency in percentage	%
Ta	Actual operating time	h
T	Total operating time	h

Exercise. 2-8, 2-9

b) Functional efficiency

Functional efficiency is the ratio of the actual effectiveness of a machine to its theoretical effectiveness, expressed in percent. Threshing efficiency of a combine is an example of a functional efficiency.

Refer to Table A-216. Field Efficiency in appendix

2-1-5.How to obtain the Effective Field Capacity

1. Actual effective field capacity will be measured at actual farm work or experiment by time study.
2. Or, Actual effective field capacity will be estimated by calculation using theoretical field capacity and field efficiency, when no data of effective field capacity is directly obtained.

a) Daily experience or Past data-base

Farmers know how many hours required for certain farm work by certain machines in their own field. This is Effective Field Capacity.
Data-base is powerful to find the useful data for planning.
Simple data-base will be build up by spread-sheet software, instead of the data-base software like “ACCESS”. Refer to fm-211.xls /db-efc-1.

b) Total operating time

$$T = ta + tb + tc + td + te + tf + tg + th \qquad \text{Eq. 2-1-10}$$

Where,

T	Total operating time
ta	Actual operating time
tb	Turning time
tc	Adjusting or Regulating time
td	Rest time
te	Loading or unloading time
tf	Transporting time
tg	Waiting time
th	Supplementing time

Total operating time will be measured by time study.

Exercise. 2-5

c) Time Study

Motion-and-time study is defined as determining the time necessary to perform motions required for a particular job.

d) Work time for certain farm work

Farm Work will be operated with a certain farm facilities set, and it includes certain machine set and workers.

Example: Threshing by machine (Self propel type)

symbol	Term	unit	data
	Farm Work	-	Threshing by machine
A	Field area	ha	0.1
Nw	Number of workers	-	3
ta	Actual operating time	min	47
tb	Turning time	min	9
td	Regulating time	min	4
(T)	Total time by 1 set of Machine	min	60
T	Time required of a set	h	1.0
(MH)	Total labor time: Man-hours	min	180
MH	Total labor time: Man-hours	man*h	3.0
EFC	Effective Field Capacity	ha/h	0.1

e) Machine or implement

Operating time of machine should be measured, even if it is automatic machine or farm robot.
If more than 2 machine sets are used for a farm work, then accumulated time should be counted for total time. After that, the value should be converted to it on a set.

f) Operator and Labor

Total time of manual work without machinery should be the accumulated time of all workers. And the value of time on a worker is shown as Effective Field Capacity of manual work.

MH = T * Nw **Eq. 2-1-11**

EFC = A / MH **Eq. 2-1-12**

Where,

symbol	term	unit	Example
	Farm Work	-	Manual weeding
A	Field area	ha	0.1
Nw	Number of workers	-	2
T	Time required	h	1.5
MH	Labor required (Man hours)	h	3.0
EFC	Effective Field Capacity	ha/h	0.033

2-1-6.Estimation by calculation

Effective Field capacity and work capacity are estimated by following equation normally for planning.

EFC = TFC * fe **Eq. 2-1-13**

TFC = W * V * 0.1 **Eq. 2-1-13a**

EFC = TFC * FE / 100 **Eq. 2-1-13b**

a) How to obtain theoretical operation width

Theoretical operation width is the measured width of the working portion of a machine. For row crop machine, it is the average row width times the number of rows.

(i) The width of implement (machine width)

It is defined by using machinery standard (usually shown by catalogue).

(ii) Planned operation width

This operation width is used for making the utilization plan of farm machinery under given detail work circumstances.

For example, in the spraying operations with two stokes on 30 meters width of field, its operation width is estimated as 15m, even if the possible width of the swath sprayer is 20 meters.

We will use above (i) and (ii) operation width shown in table 2-1-1 as theoretical operation width (Wt).

Exercise. 2-7

b) How to obtain theoretical operation speed

Field speed is defined in ASAE like as; Average rate of machine travel in the field during an uninterrupted period of functional activity. For example, functional activity would be interrupted when the implement is raised out of the soil.

Operation speed is indicated with speed of straight movement of work. The travel speed is varied by the following facts:

1. Condition of soil texture, moisture contents, shape and inclination of the field.
2. The level or rate of operator’s skill
3. The size of tractor and machine

Standard operation speed is shown in Table 2-1-1.

General operation speed is shown in Table A-211 in appendix.

We will use these rated or standard operation speed as theoretical operation speed (Vt).

c) Effective field capacity in case of tillage by power tiller

symbol	term	unit	Example
W	Width	m	0.7
V	Speed	km/h	1.2
TFC	Theoretical Field Capacity	ha/h	0.0840
FE	Field Efficiency	%	90.0
EFC	Effective Field Capacity	ha/h	0.0756
WC	Work capacity	h/ha	13.2

Refer to fm-22 .xls and TFC-EFC.xls

d) Effective field capacity in case of manual weeding

EFC-manual = Area / Time required by one worker

e) Effective field capacity in case of automatic grain dryer

Effective field capacity will be explained in detail, as of machine working time, or as of time required for operator.

Exercise. 2-10, 2-11, 2-12

Table 2-1-1 Theoretical operation width and standard operation speed

Farm work	Field	Work	Machine	Theoretical operation width	Standard operation speed
					(km/h)
Tillage, land preparation	Paddy	Tillage	Bottom-plow, Japanese plow	Shear width	6.0
	Paddy	Tillage	Rotary(<20PS)	Machine width	2.0
	Paddy	Tillage	Rotary(>30PS)	Machine width	2.5
	Paddy	Harrow and puddling	Rotary	Machine width	3.0
	Paddy, upland	Leveling	Tooth harrow	Machine width	7.0
	Paddy	Puddling	Paddy harrow	Machine width	4.0
	Paddy, upland	Harrow and leveling	One-way harrow	Machine width	6.0
	Paddy, upland	Pressing	Culti-packer	Machine width	6.0
	Paddy	Pan braking	Sub-soiler	Planning width	3.6
Fertilizing, Seeding	Paddy, upland	Manure spreading	Manure spreader	Planning width	7.0
	Paddy, upland	Fertilizing	Broad caster	Planning width	6.0
	Paddy, upland	Ridging	Ridge	Row width x Row number	5.0
	Paddy, upland	Fertilizing and seeding	Seed drill	Row width x Row number	6.0
	Paddy	Fertilizing and seeding	Fertilize seeder	Row width x Row number	2.0
	Paddy, upland	Fertilizing and seeding	Fertilize seeder	Row width x Row number	2.5
Trans-planting	Paddy	Rice transplanting	Rice transplanter	Row width x Row number	2.3
	Paddy	Rice transplanting	Rice transplanter (rotary type)	Row width x Row number	3.0
Harvesting	Paddy, upland	Chemical application	Wide swath sprayer	Rated working width	2.5
	Paddy, upland	Chemical application	Boom sprayer	Nozzle interval x its number	5.0
	Paddy, upland	Harvest (rice)	Combine	Cutting width	2.5
	Paddy, upland	Harvest (wheat)	Combine	Cutting width	4.2
	Paddy, upland	Pick and baling	Hay baler	Windrowing width	6.0
	Paddy, upland	Reaping	Binder	Cutting width	6.0

Source: JSAM: Handbook of Bio-production Machinery, 1996

2-1-7.What factors affect on the Effective Field Capacity

(Analysis and discussion)

Even if the area is the same, the field efficiency of plowing varies. The higher ratio of the long side to the short side has larger value of the field efficiency.

As field efficiency varies with shape, size operation method and operator's skill, the numbers in Table A-232 will be the standard to field the actual effective field capacity form the theoretical field capacity.

a) Machinery

(i) Width
(ii) Speed
(iii) Power

b) Field condition

(i) Size of field
(ii) Shape of field

The filed size and shape will affect effective field capacity and work capacity, like as shown in Table A-411 in appendix.

Refer to fm-232.xls

Exercise. 2-13

c) Head land

d) Inclination of field

e) Soil condition [1]

(i) Soil texture
(ii) Soil hardness

Cone penetrometer, Falling cone, Footprint depth, Hardpan

(1) SR-2 Soil resistance tester
(2) Depth of human footprint

[1] Soil physical properties

Table 2-1-2 Depth of human footprint in paddy field

Standard judgement for trafficability of tractor and combine

	Tractor			Combine clearance		
	Rotary	Bottom plow	Bottom plow with girdle	<10cm	10-20cm	>20cm
Footprint depth	cm			cm		
easy	<2	0	<1	<2	<3	<4
limit of possible	2-5	0-2	1-5	2-5	3-7	4-10
impossible	>5	>2	>5	>5	>5	>10

(iii) Moisture contents

f) Farm road, Location and distribution of fields

g) Crop condition

(i) Variety
(ii) Yield

h) Skill or health condition of operator

Skill or health condition of operator will affect actually to the rate of works.
Refer to fm216.xls

2-2. Daily Capacity

Daily Capacity will be expressed the value on a farm work by several sets of machine with operators in the several field blocks on a day. In manual farm work, Daily Capacity will be expressed the value by a group of several workers.

2-2-1.Daily Capacity

DC = EFC * Dn (* M * Nw) **Eq. 2-2-1**

Dn = Dt * NWR / 100 **Eq. 2-2-2**

Where,

symbol	term	unit	Example
DC	Daily Capacity	ha/d	3.2
EFC	Effective Field Capacity	ha/h	0.5
Dn	Net Work hours per day	h/d	6.4
Dt	Working hours per day	h/d	8.0
NWR	Daily net working rate	%	80.0

Assume M=1 and Nw = 1

a) Example: Table 2-2-1. Daily Capacity: appendix\fm-241DC.xls

Table 2-2-1 Daily Capacity

Farm work Name			Tillage	Weeding	Sowing	Transplanting	Chemical application	Harvesting
Main machine Name			Walking Tractor	Manual	Walking Tractor and Seeder	Rice transplanter	Boom sprayer	Head-feeding combine
Effective Field Capacity	EFC	ha/h	0.083	0.009	0.126	0.036	0.273	0.052
Work Capacity	WC	h/ha	12.0	111.1	7.9	27.8	3.7	19.2
Work hour per day	Dt	h/d	8.0	8.0	8.0	10.0	8.0	8.0
Net Work rate	NWR	%	75	80	65	73	75	68
Net Work hours	Dn	h/d	6.0	6.4	5.2	7.3	6.0	5.4
Daily Capacity	DC	ha/d	0.50	0.06	0.66	0.26	1.64	0.28

Exercise. 2-14

2-2-2.Daily working hours

Dt = Dn + Dp + Ds + Dc + Df + Da + Dm + Dr + Db **Eq. 2-2-3**

Where,

symbol	term	unit
Dt	Total daily working hours	h
Dn	Net working hours	h
Dp	Preparation time of work	h
Ds	Time for setting	h
Dc	Time for cleaning of farm machines	h
Df	Time for feeding	h
Da	Adjustment time	h
Dm	Moving or traveling time	h
Dr	Repairing time	h
Db	Short brake time or time for non operation or lunch time	h

a) Example: Table 2-2-2.and appendix\fm-242Dt.xls

Table 2-2-2 Actual survey of daily work hours

(Harrowing by disk harrow, and plowing)

Items	Clock Time			Items of required hours								
	Starting time	Ending time	Net hours	Working hours: Dn		Other extra hours						
				Plow	Disk harrow	Dp	Db	Ds	Dc + Df	Da	Dm	Dr
	h.min											
Garage-Field 1	7.02	7.19	17					2	10		5	
Field 1	7.19	9.53	2.34	2.31		3						
Field 2	9.53	11.15	1.22	1.07		3	10				2	
Field 2-Garage	11.15	11.44	29			4	9		10		6	
Lunch Time	11.44	13.31	1.47				1.47					
Garage-Field 3	13.31	13.39	8			1					4	3
Field 3	13.39	17.00	3.21	3.19		2						
Field 3-Garage	17.00	17.12	12					7			4	1
Garage-Field 1	17.12	17.21	9								5	4
Field 1	17.21	18.34	1.15		1.14							1
Field 1-Garage	18.3	18.53	17					2	10		5	
Total (min)	7.2	18.53	711	417	74	13	126	11	30		31	9
Rate (%)			100	58.6	10.4	1.8	17.7	1.5	4.2		4.4	1.3
	Daily net working rate								69.0 %			

Exercise. 2-15

2-2-3.Daily net working rate

NWR = Dn / Dt * 100 **Eq. 2-2-4**

Where,

symbol	term	unit	Example
NWR	Daily net working rate	%	75.0
Dn	Net working hours	h	6.0
Dt	Total daily working hours	h	8.0

a) Example: Refer to fm-243a.xls

Most of NWR is 60 to 85 %.

Exercise. 2-16

2-2-4. What factors affect on the daily capacity

a) Farm work type (Crop and customs of farmer etc.)

b) Weather condition (Length of daytime, temperature etc.)

Table 2-2-3 Working hours per day in Japan

month North latitude (name of place	January	February	March	April	May	June	July	August	September	October	November	December
26.13 (Naha, Okinawa)	8.8	8.4	9.0	9.9	10.5	10.8	10.6	10.0	9.3	8.5	7.8	7.5
35.30 (Tokyo, Ibaraki)	7.1	7.9	9.0	10.1	11.0	11.5	11.3	10.6	9.4	8.4	7.5	6.9

Remarks: These average monthly operation hours are decided from monthly average sun shining hours deduct 3 hours for lunch time and rest time.

c) Labor Standard Law: 8 hours per day in Japan

d) Scattering of fields

Field map

e) Farm road

Table 2-2-4 Farm road conditions

Effective width	machine width + 1 m	Standard
	>2.5 m	Tractor (30PS)
	>3.0 m	Tractor (40-80PS)
	>4.0 m	Tractor (>90PS)
Junction width	>3 m	
Height between paddy field and road	<30cm	Tractor
	<20cm	Combine(0.8-1.2m)
	<25cm	Combine(1.2-3.5m)
	<40cm	Combine(>3.5m)