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Role of Forest Inventory in Sustainable Forest Management: A Review

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Abstract: *An accurate assessment of forest and tree resources is needed and very essential for formulating sound forest management strategies and decision-making (sustainable management).Inventory is central to forest management and it helps to address forest degradation and deforestation while increasing indirect benefits to people and the environment; without forest inventory, forest management would not be sustainable since there would not be sufficient information for planning and implementation. The key role of forest inventory in sustainable forest management cannot be under-rated and includes provisions of information used to develop Predictive Equations (models) used for decision-making and sustainable forest management; provides information for site management, silviculture (thinning), fixing of rotation age, timber harvests; provides information for site quality assessment (site index), et cetera. For a sustainable world forest and its resources to be managed as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. However, there is need for information on forest resources and wildlife. Inventory which has been a vital tool in the management of forests for sustainable production through the information gathered, help the foresters to establish and managed forests properly with ease for sustainable development to mankind. Forest inventory information is obtained from measurements of individual trees or stand used in assessing tree and forest resources; provides qualitative and quantitative information on extent, state, use, management of the resources and enhances forest planning. The information may be obtained from measurements taken from ground or on remote sensing imagery.*

Keywords: *Forest; Inventory; Sustainable; Management; Information; Equations (models).*

1. Introduction

Protection and rational utilization of natural resources become more and more important in order to meet the increasing demand for wood raw material, Tourism and Non-Timber Forest Products (NTFPs). Among the natural resources, forests are important not only as a source of wood but as the means of protecting the hills thereby regulating stream flow, water shed protection, and reducing the rate of soil erosion, for tourism, NTFPs provision, wildlife protection among many others, (Zerihun and Yemir, 2013). Maximum advantages and benefits from forests can only be secured provided that the existing forests are properly managed. Sound forest management depends on the quantity and quality of information available on the forest.

Forest management is concerned with efficient planning so that the forest provides the greatest possible benefits such as productive forest resources, watersheds protection, tourism, NTFPs, wildlife protection, environmental protection, et cetera to the present and future generations. Forest Management as an art and science implies various degrees of deliberate human intervention, ranging from actions aimed at safeguarding and maintaining the forest ecosystem and its functions, to favoring specific socially or economically valuable species or groups of species for the improved production of goods and services.

Basic data and information is required if a renewable natural resource such as a forest is to be managed in a reasonable and sustainable manner. This information is largely obtained through forest inventories, (Zerihun and Yemir, 2013).

1.1. Sustainable Forest Management

The sustainable of forest management has become an issue in the past decade, out of concerns of both overexploiting the resource (Powers, 2001; Robert, 2003), and climate change effects to mankind (Schwalm and Ek, 2001). Sustainable Forest management is difficult to define as reported by Amaranthus, (1997) and, when defined, is hard to measure.

According to Global Environmental Facility, 2013 (GEF), noted that there is no universally agreed-on definition for Sustainable Forest Management (SFM). The GEF fully supports the definition, which states: “Sustainable forest management as a dynamic and evolving concept that aims to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations.”

According to Robert (2003), sustainable in its broadest sense implies an ability for the productivity and ecological integrity of the forest to be maintained in perpetuity. This idea is conditioned on two different yet interacting scales as noted by Robert which include: sustainable over what time period, and over what size area? Wilson and Wang (1999) defined sustainable forestry as comprising a host of management regimes to maintain and enhance the long-term health and integrity of forest ecosystems and forest-dependent communities, while providing ecological, economic, social, and cultural opportunities for the benefit of present and future generations. This definition included the biological, sociological, political, and economic factors (Perry and Amaranthus, 1997; Wilson and Wang, 1999; Robert 2003).

However, concerns from sustained forest yield to sustainable forest management was first internationally initiated by the Brundt land Report on sustainable development in 1987 (World Commission on Environment and Development, 1987) and later taken as an idea at the Earth Summit in Rio de Janeiro in 1992, with the adoption of the Forest Principles (Tittler *et al.*, 2001; Robert 2003). In response, several initiatives and international agreements have been forged to attempt to quantify broad-scale sustainable (Mendoza and Prabhu, 2000; Tittler *et al*., 2001), such as the Montreal Accord (Mihajlovich, 2001).

American Forest & Paper Association (AF and PA) (1999), looked at sustainable forestry as meeting the needs of the present without compromising the ability of future generations to meet their own needs; they considered responsible forest practices to be sustainable forestry practices that are both economically and environmentally responsible.

1.2. Aims of Sustainable Forest Management

Sustainable forest management addresses forest degradation and deforestation while increasing direct benefits to people and the environment. At the social level, sustainable forest management contributes to livelihoods, income generation and employment. At the environmental level, it contributes to important services such as carbon sequestration and water, soil and biodiversity conservation, (www.fao.org/forestry/sfm/85084/en..........2nd April, 2015).

1.3. Forest Inventory

Forest inventory serves as a very important tool in forest management; it provides the data for planning, monitoring, evaluation, research, growth and yield, timber sale. It is an attempt to describe quantity, quality and stocking density (diameter distribution) of forest trees and many characteristics of land upon which trees are growing towards the efficient and sustainable management of the forest ecosystem.

Zerihun and Yemir, (2013), reported that forest inventory is defined in different ways by different authors, but essentially with more or less the same meaning. Forest inventory: is a tool that provides the information about size and shape of the area as well as qualitative and/or quantitative information on the growing stock within the forest ecosystem. Forest inventories are designed to measure the extent, quantity, composition, and condition of forest resources, (Kangas *et al.*, 2006). Therefore, Forest inventory is the systematic collection of data and forest information for assessment or analysis; it is a systematic collection of data because there are procedures or steps to follow during data collection to ensure accuracy and precision.

Michael *et al.*, (2008), stated that “support of sustainable forest management, up-to-date forest inventories are required to assess the composition, structure, and distribution of forest vegetation that, in turn, can be used as base information for management decisions". He also reported that at the operational level, forest inventories are used for harvest planning, road layout, assessment of growing stock, and planning of silvicultural activities. At the strategic level, forest inventories provide data for long-term forest management plans and, in concert, support a multitude of decisions relevant to forest protection and wildlife management.

1.4. Types Of Forest Inventory for Sustainable Forest Management

According to Zerihun and Yemir (2013), three broad classes of forest inventories can be considered based on the depth of the investigation:

- **Reconnaissance Inventory:** this class of inventory is based upon an exploratory investigation of the forest population. The information derived is primarily intended for preliminary management decisions. The inventory data are summarized on a regional or total area basis, (Vaardman, 2008).
- **Management Inventory:** this inventory represents a low intensity investigation of a large tract of forested area; for example, a forest reserve. The information produced is primarily intended for broad-based management decisions, allowable cut calculations and long range planning.
- **Operational Inventory:** an operational inventory is based upon an intensive investigation of a relatively small area. The information produced is primarily intended for use in short term or "operational" planning, e.g. related to the harvesting of timber volumes within local cutting compartments or logging units.

2. ROLES OF INVENTORY IN SUSTAINABLE FOREST MANAGEMENT

Inventory is focus to forest management; without forest inventory, forest management would not be sustainable since there would not be sufficient data for planning or decision-making and implementation. Forest inventory assesses tree and forest resources, it also provides qualitative and quantitative information on extent, state, use, management of the resources and enhances forest planning; it promotes sustainable forest management through the provision of information about the forest characteristics.

2.1. Forest Inventory Provides Data or Information about Forest Estates

Wenger (2013) reported that forest inventory provides vital information about forest estates (biotic and abioti) which is very useful for sustainable forest management; this information includes:

- forest growing conditions
- standing timber volume, (diameter and height)
- forest stock (estimate qualitative and quantitative) resources
- resource planning
- estimate the annual growth & net worth statement in the forest
- forest composition and topographic information.
- wildlife population
- tourism potentials
- forest hydrology.
- forest species (vegetation and wildlife) composition
- assessment of potential fire hazards and the risk of fire.
- assessment of carbon sequestration of the forest.
- assessment of Non-timber forest products (NTFPs), etc.

2.2. Forest Inventory Provides Data used to Develop Predictive Equations used for Sustainable Forest Management (Figures 1 And 2).

Predictive equations assist forest researchers and managers in sustainable forests (include the ability to predict future yields and to explore silvicultural options). It provides an efficient way to prepare resource forecasts, enhance the ability of foresters to explore management options and silvicultural alternatives. For example, foresters may wish to know the long-term effect on both the forest and on future harvests, of a particular silvicultural decision, such as changing the cutting limits for harvesting. For example, with growth and yield equations, they can examine the likely outcomes, both with the intended and alternative cutting limits, and can make their decision objectively. The process of developing a growth equation may also offer interesting new insights into stand dynamics.

Inventory equations of various kinds have been very useful to forest managers for sustainable forest management. The most basic equations provide an estimate of how much forest resources are available, what it may be worth on the market and how it would be sustained from the present to future generation.

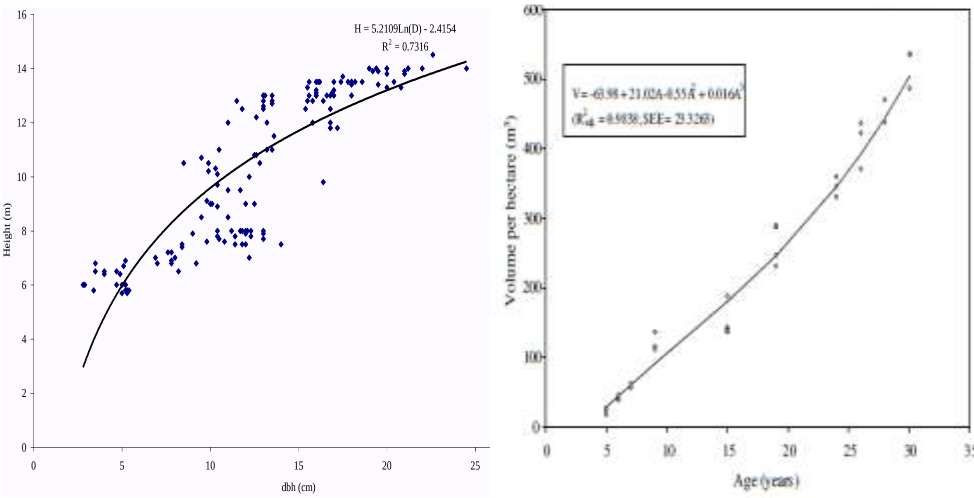

Figure1. *Height and volume predictive equation for management purposes.*

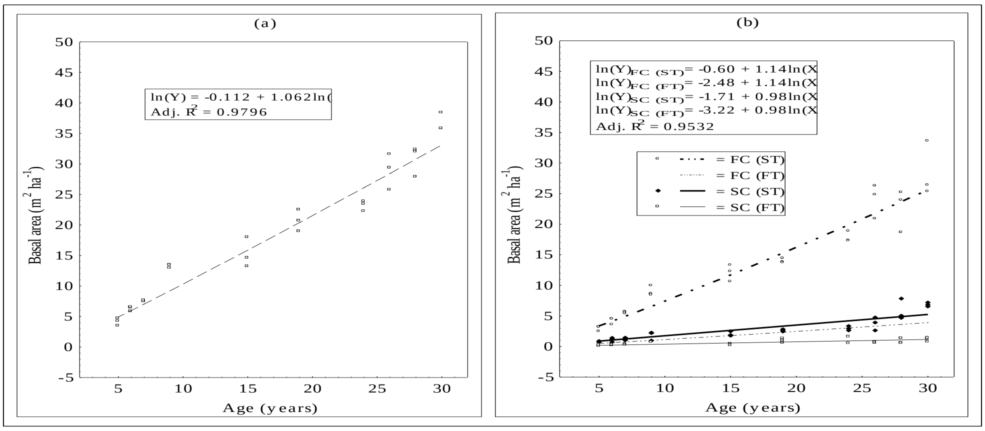

Figure2. *Stand Basal area predictive equation for forest plantation management*

Source: *Onyekwelu, (2001).*

Note: Sometimes, the interest is not to compare variables but to examine the trend of a variable given the other variables or to predict the value of one variable given the value of the others.

2.3. Forest Inventory Provides Information for Site Management, Silviculture Decision- Making, Fixing of Rotation Age, Timber Harvests, Etc (Figure 3 And 4).

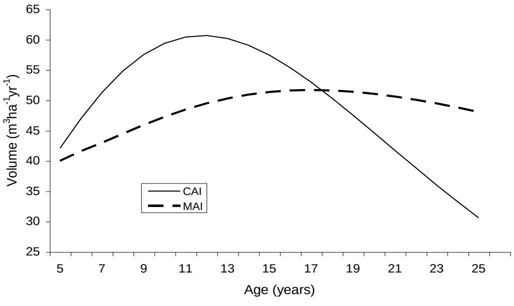

Figure3. *Relationship between Current Annual Increment (CAI) and mean annual volume increment (MAI) in Gmelina arborea plantations in Nigeria*

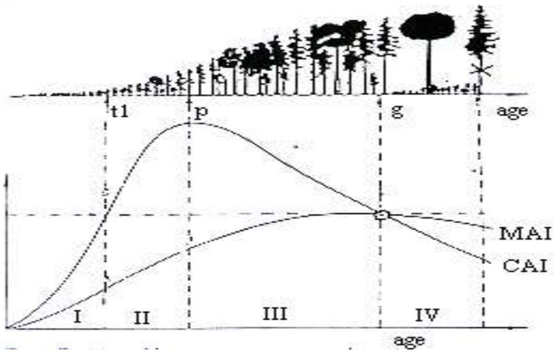

Figure4. *Mean annual increment (MAI) and Current Annual Increment (CAI) models for forest plantations management*

Source: *Onyekwelu, (2014), (**Unpublished**)*

CAI: amount of wood (in $m^3ha^{-1}yr^{-1}$) added to a tree/forest stand in a given year. (i.e. Yield of current year minus yield of previous year.

MAI: is the average amount of volume accumulated each year over the lifetime of the tree/stand. It is determined by dividing the total accumulated volume by the number of years it took to accumulate the volume.

Mean annual increment (MAI) and Current Annual Increment (CAI) models for decision making in forest plantations management also serve as guide in making thinning decisions for species plantations in sustainable forest management; the MAI and CAI models used in sustainable forestry to determine the time of first and subsequent thinning, when thinning is effective and not. MAI provides the best estimate of the maximum production rate that can be sustained by a combination of species and site quality, provided that stands are not replaced much before or after maximum MAI age. The peak of MAI is key for determining how much can be harvested annually if a forest is managed to produce a sustained-yield of timber and how long the rotations should be to maximize production. If the CAI of a given stand exceeds the simultaneous MAI, this means that the stand has not yet reached the culmination of MAI, the stand cannot be harvested. The point that CAI equals MAI is called the culmination of MAI, it is the point of maximum volume production potentials of a site. This point should be the ideal rotation age if the objective of management is maximum volume production (e.g. fuelwood, pulpwood, etc). Thus, the stand should be harvested at culmination age if the objective of management is fuelwood or pulpwood. However, where the objective of management is timber or veneerlog, the stand should only be harvested at culmination age if the trees have exceeded minimum size requirement and if there is a market. Where the trees have not exceeded minimum size requirement, they are allowed to continue growing beyond culmination age. Thinning should be administered between canopy closure and the culmination of MAI. Beyond culmination age, the trees only react minimally to thinning.

2.4. **Forest Inventory Provides Data for Site Quality Assessment (Site Index) (Figure 4). Site Index is** the timber production potentials of a site for a particular species at a given index age. . I to V are the site classes for *Nauclea diderrichii* plantations in omo forest reserve, Nigeria.

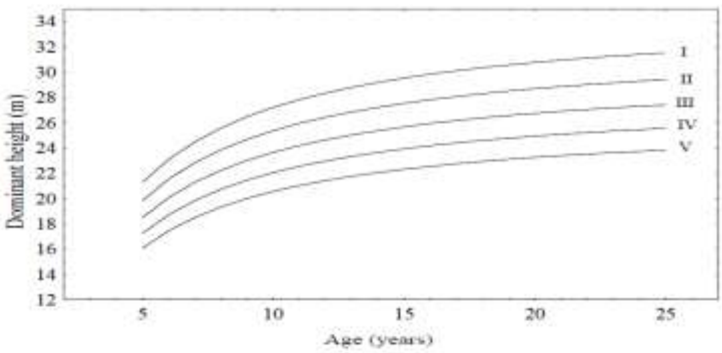

Figure5. *Site index curves for Nauclea diderrichii plantations constructed*

Source: *Onyekwelu, (2003).*

Site quality assessment is the evaluation of innate productive capacity of an area of forest land for one or more tree species. Site quality assessment is very important in forest management because a site could support one species excellently while supporting another species poorly. The oldest, commonest and most widely used technique for evaluating site quality or productivity of even-aged stands is site index **(**Onyekwelu, 2005). Site index equations are essential elements of quantitative tools in forest management (Teshome & Petty 2000). It can be evaluated mathematically or graphically. Information from sites index curves is used to manage current and future indigenous and exotic specie plantations as observed by Onyekwelu, (2003 and 2005).

The results obtained from site index assessments pave way(s) for large-scale plantations for sustainable forest management of Opepe species**.** A good information or knowledge of species growth and yield is necessary for the formulation and implementation of sustainable forest management plans, especially silvicultural decision-making processes (time of first and subsequent thinning). The site index curve developed through forest inventory would be useful in identifying suitable sites for large-scale establishment of specie plantations; to quantify its growth and yield on various site conditions.

Site index curves usually reveal the best sites for future specific special plantations. For example, in Omo Forest Reserve were site classes I, II and III due to their above average and average dominant height development (Figure 4) can be used for opepe plantation establishment as much as possible, while site classes IV and V should not be used for Opepe plantation establishment since height development of the species within these sites was poor, Onyekwelu (2005). For example, Teshome and Petty (2000) used site index curve to **assess** a ***Cupressus lusitanica*** plantation in Ethiopia, they recommended the first thinning to be carried out at the attainment of dominant height of 11 m for site classes 27, 21 and 12 at ages five, seven and 13 years respectively. While, the thinning schedules developed for Opepe plantations as recommended by Dupuy and Mille (1993) and Onyekwelu (2001) indicated that first, second and third thinnings, should be administered at the attainment of average dominant heights of 13, 17 and 22 m respectively, for sustainable forest management to mankind.

3. CONCLUSION

Forest Inventory information use for forest decision-making (policies) and management, fixing of rotation age, site management, timber harvests, predictive equations and silvilculture practice enable forest managers to determine the economic feasibility of timber harvest and NTFPs. Predictive equations/models give better and reliable information for estimates of forest timber and NTFPs, include other forest characteristics. Forest inventory provide equations or information for growth and yield prediction which tend to portrait a better pictures of a forest and its characteristics in a more distant future. These equations help give the background in which a stand-level forest management decision is made, giving a forester a better understanding of the implications one action has on other areas.

Forest inventory as a vital tool in the management of forests and its resources for sustainable production and management through the gathering of information which helps the foresters to establish and managed forest estates properly with ease for sustainable development to mankind.

Therefore, forest inventories information has been used in forest fire preventative actions, awareness and also management information.

4. RECOMMENDATION

However, more emphasis should be placed on frequent assessment of forest and wildlife resources to ensure update information of our forest estates/plantations especially indigenous tree species in Africa; to avoid extinctions and to control the rate of deforestation which has a great impact on the lives of future generation.

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REFERENCES

[1] Amaranthus, M.R (1997): Forest sustainability: an approach to definition and assessment. Gen. Tech. Rep. PNW-GTR-416. Portland OR: USDA Forest Service, Pacific Northwest Research Station. 14 p.

[2] American Forest & Paper Association (AF and PA) 1999: Sustainable Forestry lnitiatives Standard: Principles and Objectives. American Forest & Paper Association, Washington, DC.5 p.

[3] Dupuy, D. and Mille, D. (1993): Timber plantations in the humid tropics of Africa. FAO Forestry Paper 98. Rome.

[4] Global Environmental Facility (2013): (www.gef.com/.............April, 2015).

[5] Goff, G.R. (1994): Timber Management for Small Woodlands. Inf. Bull. 147IB180rev. N.Y.S. Coll. of Agr.and Life Sci., Cornell University, Ithaca, N.Y. 57 pp. http://www.bodley.ox.ac.uk /users/millsr/isbes/ODLF/IP32.pdf........November,2014

[6] Kangas, A., J.H. Gove and C.T. Scott. (2006): Introduction. In A. Kangas and M. Maltamo.Forest Inventory. pp. 3–11. Springer, the Netherlands.

[7] Mendoza, G.A. and R. Prabhu.(2000): Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management. Forest Ecology and Management 131:107-126.

[8] Michael, A. W.; Christopher, W. B.; Nicholas, C. C.; Thomas, H. and Joanne, C. W. (2008): The role of LiDAR in sustainable forest management; The Forestry Chronicle, Vol. 84, No. 6; Pp: 807-826.

[9] Mihajlovich, M. (2001): Does forest certification assure sustainability? Forestry Chronicle 77(6): 994- 997.

[10] Onyekwelu, J. C.(2005): Site Index Curves for Site Quality Assessment of Naucleadiderrichii Monoculture Plantations in Omo Forest Reserve, Nigeria; Journal of Tropical Forest Science54217(4): pp: 532—542.

[11] Onyekwelu, J.C., (2001): Growth characteristics and management scenarios for plantation-grown Gmelina arborea and Nauclea diderrichii in south-western Nigeria. Published Ph.D. Thesis, Department of Silviculture and Forest Management, Technical University of Munich, Germany.Hieronymus Publishers, Munich Germany; ISBN 3-89791-235-X, 201 pp.

[12] Onyekwelu, J.C., (2003): Choosing appropriate index age for estimating site index of Gmelinaarborea timber plantations in Oluwa forest reserve, Nigeria. Journal of Food, Agric. & Environment, 1(3&4): 286 – 290.

[13] Perry, D.A., and Amaranthus, M.P. (1997): Disturbance, recovery, and stability. P. 31-56 in: Kohm, K.A., and Franklin, J.F. (eds.), Creating a forest for the 2lst century. Island Press, Washington, DC.

[14] Powers, R.F. (2001): Assessing Potential Sustainable Wood Yield. In: The Forestry Handbook. J. Evans (Ed.) Vol 2. Applying Forest Science for Sustainable Management. Blackwell Science, Ltd. Oxford, UK. P. 105-128.

[15] Robert A. Monserud (2003): Evaluating Forest Models in a Sustainable Forest Management Context; FBMIS Volume1; pp: 35-47; ISSN: 1740-5955; http://www.fbmis.info/A /3_1_ MonserudR_1.

[16] Schwalm C. and Ek,A. R. (2001): Climate change and site: relevant mechanisms and modeling techniques. Forest Ecology and Management 150: 241-257.

[17] Teshome, T. and Petty, J. A. 2000. Site index equation for Cupressuslusitanica stands in Munessa, Ethiopia. Forest Ecology and Management 126: 339–347.

[18] Tittler, R., C. Messier and P.I. Burton (2001): Hierarchical forest management planning and sustainable forest management in the boreal forest. Forestry Chronicle 77(6): 998-1005.

[19] Vaardman, J.M. (2008): How to Make Money Growing Trees. John Wiley & Sons, Inc., New York. 296 pp.

[20] Watson, R.T. M.C. Zinyowera, and R.H. Moss (Eds) (1995): Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK. pp 878.

[21] Wenger, K.F., (ed) (2013): Forestry Handbook. John Wiley and Sons, Inc., New York. 1,335 pp.

[22] Wilson, B. and Wang S. (1999): Sustainable forestry--the policy prescription in British Columbia. In: Yoshimoto, A and K. Yukutake, eds.). Global Concerns for Forest Resource Utilization-- Sustainable Use and Management. Kluwer Academic Publishers, London. P. 35-45.

World Commission on Environment and Development (1987): Our common future: report of the World Commission on Environment and Development. Oxford University Press, New York. New York, USA. www.fao.org/forestry/sfm/85084/en..........2nd April, 2015

[23] Zerihun A. andYemir T. (2013): Hawassa University: Wondo Genet Colleg of Forestry and Natural Resources, Training Manual on: Forest Inventory and Management in the Context of SFM & REDD. Pp. 1-67.

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