Adriana de Miranda

WATER ARCHITECTURE IN THE LANDS OF SYRIA

THE WATER-WHEELS

«L'ERMA» di BRETSCHNEIDER

Adriana de Miranda

WATER ARCHITECTURE IN THE LANDS OF SYRIA: THE WATER-WHEELS

«L'ERMA» di BRETSCHNEIDER

Adriana de Miranda
Water Architecture in the lands of Syria: the Water-Wheels

Via Cassiodoro, 19 - 00193 Roma
http://www.lerma.it

Progetto grafico:
«L'ERMA» di BRETSCHNEIDER

De Miranda, Adriana
Water Architecture in the Lands of Syria : the Water Wheels / Adriana de Miranda. - Roma : «L'ERMA» di BRETSCHNEIDER, 2007. - 376 p. : ill. ; 24 cm. - (Studia Archaeologica ; 156)
ISBN 88-8265-433-8

CDD 21. 714

1. Molini ad acqua – Architettura – Antichità
2. Ruote idrauliche - Siria

CONTENTS

ABSTRACT

This work aims to evaluate the typology of water-wheels in Syria as an ancient type of water architecture which has had a fundamental role, over the centuries, for irrigation and supplying water to houses and public constructions. So far these devices have been studied in terms of their hydraulic and technological aspects, while their architectural and artistic qualities have often been neglected. The research provides a historical, architectural and iconographical study of these structures, focusing on those located in West Syria, where most water-wheels were built and have high artistic value. The study looks at their architectural aspects and artistic significance, and identifies precise classifications by examining the shape and design of the installations.

The work develops in three parts. The first part presents a detailed analysis of the typology and sources related to its origin and development. The second part, mainly based on architectural material and on the results of fieldwork done on the sites, highlights the cultural, historical and architectural value of the Syrian installations, showing their significant characteristics and advantages, the reasons of their uniqueness and of their wide diffusion until recent times. The third part deals with the relationship between water-wheels and modern irrigation systems, and attempts to evaluate the feasibility of renovating water-wheels as a sustainable system, as well as an example of historical and cultural heritage.

FOREWORD

1. ACKNOWLEDGEMENTS

I would like to express my appreciation and thanks to all of those who, in several ways, have provided essential contributions in making this research project possible. Among them I particularly want to express my gratitude to Dr. Eng. Muḥammad Saʿīd Akil, Governor of Ḥamā, for giving me every logistical support and assistance during my time in Syria. The others that I would like to remember, include the members of the governorate of Ḥamā, Eng. Māzīn Saffaf, Mr. Rāfiʿ Al-Ḥusayn and Mr. Misʿaf Maghmūma for introducing me to the sites and structures analysed and for their friendly and generous cooperation. From Ḥamā I also wish to thank Arch. Asʿad Daqqāq, Arch. Majd Hijazi, Director of the Department of Antiquities of Ḥamā, Arch. Rawdan Lazkani and Dr. Abdul Razzak Asfar. I would also like to thank Dr. Mundhir Hāyik, Mr. Naʿīm Zahrāwī and Dr. Dārim Tabbaʿ from Ḥoms, Dr. Suhayl Zakkar from Damascus, Dr. Maḥmūd Ḥarītānī from Aleppo and Dr. Theib Oweis from the International Centre for Agricultural Research in Dry Areas (ICARDA), Dr. Siam Bhayro and Dr. Roger Matthews from the University College of London, Dr. Anna Contadini, Dr. Geoffrey King, Prof. Andrew George and Prof. Sabry Hafez from SOAS, University of London.

My thanks also go to the staff of several libraries for having allowed me access to various source material. In particular the Bodleian Library in Oxford, the SOAS Library, the British Library, the Warburg Library and the Wellcome Library in London, the Istituto per l'Oriente C. Nallino and the Pontificia Commissione di Archeologia Sacra in Rome, the Vatican Library, the Biblioteca Ambrosiana of Milan, the Biblioteca Laurenziana and Biblioteca Centrale in Florence, and the Biblioteca Reale of Turin.

I would like also to acknowledge the Barakat Trust, the British Society for Middle Eastern Studies (BRISMES) and the Institut Français d'Études Arabes de Damas (IFEAD) for financial support during my fieldwork in Syria.

2. NOTES ON CONVENTIONS

Drawings and photographic illustrations are and indicated in the text by "Fig." in brackets. At the end of Chapter Eight there is an illustrated glossary of architectural terms utilised throughout the text. Beside each term the corresponding word transliterated from Arabic is shown in brackets, while Arab and Latin words are used where an English translation does not exist. Dates associated with Islamic history are given in *hijrī* and Gregorian terms where of particular significance. In this case the *hijrī* precedes the Gregorian. Otherwise, only the Gregorian equivalent is used. The transliteration of Arabic follows the *International Journal of Middle East Studies* system. Throughout the text, international modern names of rivers, towns and sites, are used (for example, Orontes, Aleppo, Ḥoms, Babylon, etc.). Some installations referred to in this thesis have not been published before, and their spelling is based on the verbal testimony of local people. The transliteration of Akkadian words follows the Assyriological Convention.

CHAPTER ONE

INTRODUCTION

1. SYRIAN WATER-WHEELS: AN AGE-OLD TRADITION

Many techniques were used in Syria to lift and convey water from rivers and wells. The most impressive device used was the water-wheel,[1] driven by waterpower or by animals. Water-wheels have played a leading role in a centuries-old tradition, in solving the main problem of supplying and carrying water for irrigation in Syria. Although this typology has had a fundamental role, it has been considerably underrated in art-historical writing.

Water-wheels have been studied in terms of hydraulic and technological aspects, while their architectural qualities have often been neglected. A reason for the neglect of this type of water architecture is that it has long been regarded as merely utilitarian, while its artistic connotations have largely been ignored. In addition the fact that most installations are located in isolated areas, difficult to reach, may have contributed to a scanty consideration of Syrian water-wheels.

Another reason for the lack of attention paid to these water-structures may be the fact that they have been strictly connected with the environment in which they are used, and have been correlated with the availability of surface water and groundwater. This means that their spectacular aspects and the function of their technology can be fully appreciated when the wheel is in motion. Many installations have, in fact, been completely abandoned and have fallen into disuse when people looked for new technologies which provided water much more easily.

[1] Although the correct Arabic terms for water-wheels are *nā'ūra* and *sāqiya,* throughout the text I have used the term *noria* in the singular and *norias* in the plural, because this is a universal definition used across Europe and the Middle East. Since there is no English version of *sāqiya*, I have employed the Arabic term, using *sāqiya* in the singular and *sāqiyas* in the plural.

My present research deals with the analysis of Syrian water-wheels, which were built specifically to raise water for irrigation rather than to move machinery, starting from a study of the origin of the typology and its problems in terms of terminology and classification, focusing on their architectural aspects and artistic significance, and identifying precise typological differentiation by examining the shape and design of the structures. The study focuses on the water-structures used to supply water for irrigation located in western Syria, where most installations were built and, as will be shown, have evidenced a high artistic and historical value.[2] The Syrian structures have also been evaluated as part of a wider geographical context where different regional variations have developed over the centuries. An appropriate assessment for the implementation of sustainable renovation of water-wheels has been attempted through a possible re-evaluation of these traditional types of water-architecture.

2. SOURCE MATERIALS AND APPROACH

In this study, historical records, together with the results of fieldwork, have provided a clear picture of the importance of Syrian water-wheels. Various types of material have been used in order to make possible a better understanding and interpretation of these water structures. As in Syria some water-wheels are no longer in working order, the main sources of information are written texts and visual material.

The work includes information found in treatises on architecture and hydraulic manuals, which have been used as a foundation to explain technological matters and the shapes of water-wheels.

The knowledge of medieval machinery which has permitted an understanding of the technological development and evolution of the water-structures is also derived from manuscripts and books which have provided an accurate picture of the application of such machines.

For the history of these machines our best sources are travel books and topographical works which have revealed the centuries-old tradition of water-wheels and underlined their historical importance.

The study also includes information derived from papyri, mosaics and mural paintings, and the results of archaeological excavations. They have

[2] The few remains of installations in East Syria are dealt with only in terms of any major differences with the greater number of water-wheels which have survived in West Syria on which this work focuses.

allowed a better understanding of the historical evidence and development of water-wheels. Inscriptions on some installations have also been used to assist in dating and recording construction and restoration work.

The sources of information have been combined with the results of fieldwork. Architectural data are based mainly on surveys and studies of the water-structures located in Western Syria. More than one hundred sites characterized by the presence of water-wheels have been surveyed. All findings, apart from the significant machine preserved in Damascus, are concentrated in the Orontes valley. In Aleppo and Ḥoms no remains have survived and their study is based on historical information and old reproductions.

Fieldwork done in two different seasons has allowed an exhaustive survey of the Orontes installations. In a period of low water level, as in autumn 2004, it was possible to study the complete structures, including the foundations, allowing the exact type of installation to be determined. By contrast, in spring 2005, when the river level was high enough to enable the water-structures in use to work properly, it was possible to gain a better understanding of their efficiency. Several structures have never been documented before, and are illustrated by photographs and drawings which permit a deeper understanding of these installations.

Despite the fact that the Orontes installations have been traditionally considered as based on only a single pattern, it will be shown that a variety of shapes and designs was adopted. Frequent repairs and reconstructions, and the lack of well-preserved structures from earliest periods, make dating extremely difficult. An attempt has been made to understand the possible original aqueduct and tower designs. Through this study, the results based on fieldwork combined with historical data will establish a working hypothesis rather than a definitive statement.

The study of the installations surveyed was structured in three phases. The first step was to analyse the structures and identify precise typological classifications. Secondly, by examining building techniques and architectural details, and by a comparative analysis of the installations with different ancient typologies, and with the support of historical manuals and treatises on architecture, it was possible to identify the probable original shape and to understand the evolution and development of the typology. Finally some significant examples, whose design shows interesting degrees of elaboration, have been selected and analysed in more depth, also representing the main design types of the Orontes installations.

Fieldwork has also aimed to verify the existence of remains of ancient water-wheels powered by animals, which raised water from underground, and once existed in the rural areas of north-western Syria. The most recent

documentation of the last few remains dates back to Schiøler's survey of the 1970s.[3] The surveys that I have done in these areas have ascertained the loss of surface remains of these devices. However, as will be argued, these devices have been particularly considered for their functional and utilitarian aspects, rather than for architectural characteristics, and their study has mainly been based on historical material and old reproductions.

Fieldwork has also included a survey of the modern systems of irrigation built along the Orontes, and has allowed an understanding of the relationships with traditional water-wheels powered by the river (*hydraulic norias*), how and why modern systems of irrigation replaced them, and how a re-evaluation of these traditional water-structures may be possible.

The study of Syrian hydraulic norias has clarified the uniqueness of these devices, also compared with important installations still in use in other parts of the world, in particular the Chinese examples. In order to better understand their structure and to compare them with Syrian examples, Chinese water-wheels located in the Guangxi region have been surveyed. These installations, which are numerous along the Linxi river, represent a characteristic typology which is widespread in East Asia. The fact that they are still in use to irrigate large rice fields has enabled a better understanding of their architectural details and a clear comparison with the Syrian examples.

3. RELEVANT AVAILABLE LITERATURE

Despite the general neglect of the subject, it is appropriate to consider the relevant literature devoted to the history of water-raising contrivances and Syrian devices of this kind.

Among the manuals on old technology, the most useful and detailed study carried out before the 20th century is the work by Forest de Belidor,[4] which includes large detailed drawings. It was overtaken in the 1950s by R. J. Forbes' work,[5] although neither he nor Lynn White[6] differentiate between geared and ungeared wheels. More recently the manual written

[3] Schiøler 1973, 22-24.
[4] De Belidor 1819.
[5] Forbes 1955.
[6] White 1962.

by Thorkild Schiøler[7] in the 1970s has been particularly useful for classification of the structures and for numerous impressive drawings done by the author. A modern study of water technology is in the book edited by Örjan Wikander.[8] It highlights the archaeological and written evidence for hydraulic works according to the results of four decades of historical research and offers a new basis for discussion of technical progress in antiquity. Among more ancient books, that by Georg Andreas Böckler[9] has been particularly valuable for providing interesting drawings which show a large variety of different shapes of wheels.

Particular attention has been accorded to manuscripts containing detailed technological descriptions of the structures as well as original drawings, like that by Philo of Byzantium[10] and Vitruvius,[11] who describe the function of wheels moved by the power of water, Taccola,[12] whose work contains an original drawing of a high-lift sāqiya, Leonardo da Vinci,[13] who describes four water-raising contrivances without right-angle gears, and Francesco di Giorgio Martini,[14] who also shows various water-raising machines particularly interesting for their singular composition and different methods of construction.

Valuable for a large number of imaginative drawings of water-wheels are the 16th to 18th century architectural treatises, like those by Agostino Ramelli,[15] Vittorio Zonca,[16] Francesco Veranzio[17] and Jacob Leupold[18] which show how the mechanism of water-wheels, which has remained intact over the centuries, can be combined successfully with many shapes.

[7] Schiøler 1973.

[8] Wikander 2000.

[9] Bockler 1673. This book was first published in 1661.

[10] *Hagia Sophia 3713* (Philon's water-lifting machine, folio 84r), kept in the Süleymaniye U. Kütüphanesi of Istanbul. A French translation is to be found in Carra de Vaux 1903.

[11] Cesariano 1521. The *De Architectura* by Vitruvius (1st century B.C.) was aknowledged in 1414 as the original kept in Montecassino abbey (Italy). The first printed publication in Italian, done by Cesare Cesariano in 1521, contains the best drawings from the Vitruvian originals. The English translation was done in 1960 by M.H. Morgan.

[12] The Taccola's work is the *Ms Palatino 766*, kept in the Biblioteca Nazionale of Florence.

[13] *Codice Atlantico*, preserved in the Biblioteca Ambrosiana of Milan.

[14] The *Trattato di Architettura* by Francesco di Giorgio Martini is kept in the Ms S.IV in the Biblioteca Comunale of Siena, Ms II.I.141 in the Biblioteca Nazionale of Florence, Ms 148 in the Biblioteca Reale of Turin and Ms 361 in the Biblioteca Medicea Laurenziana of Florence.

[15] Ramelli 1588.

[16] Zonca 1607.

[17] Veranzio 1615.

[18] Leupold 1724

Among the books on water-wheels built in Islamic countries, especially useful in connection with the Syrian structures are the valuable work by Joseph Townsend,[19] the studies by G. S. Colin,[20] by Laïla Ménassa and Pierre Laferrière,[21] and many others listed in the bibliography. In particular, Townsend noted an amazing relationship between the Spanish wheels and the ruins of a construction in Aleppo.[22] Particularly remarkable for the comprehension of the Islamic technology in the Syrian devices are the studies conducted by A.Y. Hassan and Donald Hill in the 1970s and 1980s.

Many travellers have been attracted by Syria. Impressed by the beauty of the landscape characterized by the water-wheels around Ḥamā, they wrote of their amazement in front of these water structures. Among the recent travel books, the Barrès report has been one of the most impressive. Although Barrès did not provide much detailed information on individual water structures, he expressed a clear awareness of the importance and beauty of these monuments. He remarked that:

> "...Jour et nuit, les grandes roués hydrauliques, quelques-unes de dimension colossale, à la fois ingégneuse et barbares, compliquées et primitives, font monter l'eau sans arrêt dans ses aqueducts. Le gémissement des lourds madriers qui, dans une pluie tourbillonnante, tournent lentement sur leur axe, forme une rumeur continue et profonde, la chanson de l'Oronte. Une chanson qui se mèle au paysage, le pénètre un attrait difficilement exprimable...".[23]

Particular attention has also been accorded to Arab literature. A very important contribution to the understanding of Arab technology is provided by al-Jazarī,[24] whose work concentrates on the artistic aspect of the illustrations and is considered one of the most important contributions to medieval technology. For the mathematical precision of the wheel design, the work by al-Ansārī[25] is particularly interesting. He considers water-lifting one of ten

[19] Townsend 1791.

[20] Colin 1932; Colin 1933.

[21] Ménassa et Laferrière 1975.

[22] As will be pointed out in Chapter Four, the construction Townsend refers to is most probably the water-wheel on the Quwayq river which existed in Aleppo until 1902.

[23] Barrès 1923, 218-219.

[24] There are 15 different copies of al-Jazarī's manuscript (1206). The earliest illustrated copy is the Ms Ahmet 3472, dating from 1206, now preserved in the Topkapi Palace at Istanbul, while in the Bodleian Library three significant illustrated copies are Ms Greaves 27 dated 1341, Ms Marsh 669 and Ms Fraser Or 186 dating from 1486.

[25] al-Ansārī (dec. 1348) is cited by Ḥajjī Khalīfa (d. 1657) whose work was translated into Latin by Gustavus Flügel in *Lexicon bibliographicum* (Ḥajjī Khalīfa 1835).

sciences derived from geometry. The Arabic translation of the first manuscript by Philo of Byzantium, mentioned above, has been fundamental in the comprehension of the origin of the wheels. Several manuscripts on Islamic technology include material on the water-wheels; among these the studies by the Banu Mūsā brothers, al-Murādī, Būzjānī and Taqī al-Dīn are especially valuable because they focus on the technical function of the water-wheels. In addition, medieval Arabic travel books, like those by Ibn Jubayr,[26] Yāqūt,[27] al-Dimashqī[28] and Ibn Baṭṭūṭa[29] describe vividly the emotions aroused by the extraordinary landscapes created by the presence of this amazing architecture on the Orontes.

Not much has been written about the architecture of Syrian water-wheels and the development of their forms. However, we have to pay tribute to the Danish architect Ejnar Fugmann who, in the 1930s, took part in an archaeological mission at Apamea directed by J. P. Riis. Fugmann started studying the Orontes installations, but could not conclude his studies.[30] The recent works by A. Zaqzūq[31] and Delpech[32] have also contributed to the knowledge of the Orontes water-wheels. However these writers are undoubtedly better trained to appreciate the technical and socio-economic achievements than the artistic qualities of these structures.

The material is divided into three main parts which include six core chapters.

The first, which corresponds to Chapter Two, concerns the historical and structural aspects of water-wheels, providing the necessary foundation for the understanding and interpretation of visual material. This part also includes the analysis of the sources relating to the origin and development of water-wheels.

The second part deals with Syrian water-wheels and includes Chapters Three, Four, Five and Seven. Chapter Three contains an analysis of sources relating to the origin of Syrian water-wheels and the following two chapters provide an architectural analysis of these structures, focusing on the most significant examples and classifying them primarily by examin-

[26] Ibn Jubayr 1952.

[27] Yāqūt 1867.

[28] al-Dimashqī 1874.

[29] Ibn Baṭṭūṭa 1853, 141-143.

[30] Ejnar Fugmann did the drawing of one of the great wheels of Ḥamā which has been published in Schiøler's work (Schiøler 1973, 8).

[31] Zaqzouq 1990.

[32] Delpech *et al.* 1997.

ing their shapes and by studying the way in which the structures draw water. This part contains the main findings of the field-work. A survey of the installations on the Orontes river is included in Chapter Seven. A map indicating the sites visited where whole or parts of installations still exist is included at the end of the book.

The third part, which corresponds to Chapter Six, deals with the development of modern systems of irrigation and their relationship with the traditional hydraulic norias and the possible re-evaluation of these ancient devices.

An architectural "Illustrated Glossary" of the most frequent terminology adopted throughout the text appears after the final chapter ("Conclusion").

It is hoped that this work will contribute to the knowledge and study of water architecture in Syria by documenting the importance of the old water-structures and that it will provide new means for understanding these installations.

CHAPTER TWO

OPEN FORMS OF WATER ARCHITECTURE: THE WATER-WHEELS
Technical and historical aspects

1. STRUCTURAL AND FUNCTIONAL CHARACTERISTICS

1.1. THE PROBLEM OF TERMINOLOGY

The system for raising water through a wooden wheel is better known as "noria" or "sāqiya". The word *noria* derives from the Arabic word *nā'ūra* (pl. *nawā'ūr*) which means "the means to irrigate which works by water and produces a sound" due to the particular sound which the wheel generates.[33]

The terms utilized by various authors to indicate different types of water-wheels often do not correspond. Up to the 19th century, water-wheels with pots moved by the force of the river were called *Persian wheels*, referring to the type most frequent in Persia.[34] Forbes,[35] Hassan and Hill[36] call a wheel with pots moved by the force of the river *noria* and the wheel with pots moved by men or animals *sāqiya*. According to Needham and Ling[37] the word *sāqiya* indicates the vertical hanging of an endless chain of pots and the word *noria* refers to a wheel with pots around its rim. Schiøler[38] considers both *noria* and *sāqiya* machines moved by the power of animals, differing in the shape of the shaft, and he calls a wheel moved

[33] Steiger 1932, 287.

[34] Ewbank 1842, 115. Already J. W. Gent, speaking about water-wheels used to raise water for irrigation, wrote that "...The most considerable and universal is the Persian wheel, much used in Persia, from whence it hath its name, where they say there are two or three hundred in a river...".

[35] Forbes 1956.

[36] Hassan & Hill 1986.

[37] Needham & Ling 1965.

[38] Schiøler 1973.

by the current of the river *hydraulic noria*, while *treadwheel* is a machine turned by the tread of one or two labourers. In the terminology utilized by Smith,[39] a *sāqiya* is simply a chain with buckets moved by man, while a *noria* is a wheel moved by water. More recently, Oleson[40] has simply used the word *wheel with compartmented body* to indicate the Vitruvian tympanum, which corresponds to the treadwheel, while for *wheel with compartmented rim* he means the wheel driven by water-power.

In addition, in some geographical areas where a number of different types of these structures are used, as in Northern Egypt, people use a generic term to cover them all. In Spain the term *noria* is used both for water-driven wheels and animal-powered wheels. Caro Baroja[41] uses two terms: *la rueda de corriente*, to indicate a wheel moved by river power, and *la noria de sangre*, to indicate a wheel moved by animals. In Syria, the term *gharrāf* is used for geared wheels, while the typology of the great wheels at Ḥāma is termed *noria*, or, more correctly, the classical form, *nā'ūra*. This term, on the other hand, is unknown in Egypt, although Europeans use the Spanish form, *noria*, when referring to the Egyptian *sāqiya*. In the vicinity of Aleppo, the *dulāb*, a word of Persian origin (*dolāb*), which is well known in Egypt, Sudan and Iraq, is used to indicate animal-powered wheels. On the other hand the word *dulāb* is used in Morocco to indicate water-wheels with compartments on the rim moved by the current of the river.[42]

Although the terminology of this machine is still not clearly defined, water-wheels are primarily divided into three types: machines moved by the power of animals, men or by water itself. In addition, for every group there are sub-classifications to indicate the different types of wheels.[43] The terminology that has been adopted here is close to that used by Schiøler,[44] which seems to be the most exhaustive.

[39] Smith 1978.

[40] Oleson 2000 (b).

[41] Baroja 1954.

[42] Colin 1933, 156.

[43] Up to the 9th century machines to raise water were not classified, despite detailed descriptions given by Philon and Vitruvius. Only with Ya'qubī (d. 891) were machines first classified into two groups: the group powered by animals or men and the group powered by the perpetual flow of the river.

[44] Schiøler 1973.

1.2. THE TYPOLOGY

1.2.1 General characteristics

In general terms the system is composed of two main parts. The first includes one or more wheels, made of wood: the second is the aqueduct, made of masonry. The former is mobile, the latter is fixed. The installation always includes a vertical wheel which is placed beside the aqueduct, on the banks of a stream or partially inserted underground and, depending on the type, it can also include one or more horizontal wheels.[45] The vertical wheel turns because of the river current or the power of animals or men. Water is raised by the wheel and poured into the channel along the top of the aqueduct. The force of gravity moves the water downwards into the cistern or irrigation channels. The wood employed to make the wheels has to be durable and flexible.[46]

There are many advantages of this kind of water-wheel: it has a simple mechanism and assembly, it is a clean technology for the environment and it has easy, low-cost maintenance requirements. Since water-wheels operate continuously, they typically require periodic partial restoration of the worn wood. The disadvantage is that part of the water is wasted when it pours into the tank (Fig.1).

1.2.2. Machines moved by animals

These machines correspond to the *sāqiya* and *noria*. They indicate the type of installation which raises water from streams or from underground to irrigate fields and gardens or to supply water for small structures. They are composed of a machine moved by the power of animals which turn a horizontal cogged-wheel made of wood, which then turns a vertical wheel with cogs.[47] The latter transmits the rotation to the main wheel of the

[45] A detailed description of the types of water-wheels is given in the following paragraphs.

[46] Many types of wood can be employed, depending on local availability. For example, in Egypt the trees used are acacia and tamarind (Menassa & Laferrière 1975, 11, 29), in Syria, mulberry, poplar, apricot and elm are the best woods employed (information about the type of wood has been provided by the "Department of the norias" at Ḥamā in 2004). In East Asia, the numerous bamboo plantations provide an excellent material for water-wheels because it is easy to split and yet strong.

[47] These machines always turn right to left, due to "a natural predisposition of men to use the right hand" (Bay 1916, 82). In fact the man incites the animal to move by using his right hand for beating the back of the beast, which is obliged to run to the left.